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DRAGON MISSILE SIMULATOR.(U)

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Dragon Missile Simulator Final Report

February 1978

U.S. Army Materiel Development and Readiness Command

HARRY DIAMOND LABORATORIES

Adelphi, Maryland 20783

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A brassboard training device that simulates the Dragon missile was developed and tested to evaluate the characteristics that are necessary for improved training of Dragon gunners. Videotape recording and a full color simulation were found to be valuable as a training aid. An audible signal indicating aiming errors was found not to be an advantage since it is not present in the real system. Further development of a training device for field use will occur after firm requirements are established.

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1. INTRODUCTION

The Dragon missile is a man-portable, shoulder-fired medium range anti-tank/assault weapon. Stationary or moving targets up to 1000-m range can be attacked. Operation is simple and automatic. The gunner is required only to keep the sight crosshairs aimed at the target until the missile hits. The Dragon is a wire-guided command-to-line-of-sight missile system designed for use in any terrain or environment which affords a line of sight to the target.

An improved training device was required for training gunners in the use of the Dragon missile. The Harry Diamond Laboratories (HDL) was tasked by the Project Manager for Training Devices (PM-TRADE), to design and develop a prototype (brassboard) device, similar to the tracker, that could be used to evaluate the training effectiveness of different characteristics. A similar device (not discussed in this report) employing a different technical approach was built by Martin-Marietta Corp., Orlando, FL. The HDL effort began on 1 December 1975. The system was delivered to Fort Benning, GA, on 11 June 1976. Field testing was initiated on 7 July 1976 and successfully completed 30 July 1976.

2. FUNCTIONAL REQUIREMENTS

A major factor affecting the Dragon gunner's proficiency is the distracting effect of the missile in the gunner's field of view. The present training device does not provide practice in resisting this distraction. The training device should present a realistic simulation of the missile in the gunner's view of the target scene. It is desirable that every distracting aspect of the missile behavior be simulated, including obstruction of the view of the target early in flight, side thruster flashes, and apparent diminishing size of the missile as the engagement proceeds. The most important effect is the violent missile motion with respect to the gunner's crosshairs. The Dragon training device must therefore provide a real time dynamic simulation of the missile's flight, closing the missile guidance loop by performing the same computation with the same accuracy and response as the tactical system.

These are the functional requirements:

a. Simulation of the missile effects includes the dynamic behavior of the missile, audible and visible side thruster firings, obstruction of the view of the target early in the engagement with apparent diminishing size of the missile as the engagement proceeds, and the blurring and apparent target motion that occurs during side thruster firings. The heated air in the vicinity of the side thruster causes refraction that momentarily blurs the gunner's view of the target and makes the target appear to move. This effect is present also just after the launch of the missile.

b. The prototype must operate with targets between 65 and 1000 m and crossing speeds of 0 to 35 km/hr.

c. An audible signal indicating aiming error will be provided to the gunner as follows: (1) No tone will be transmitted if the gunner is aiming within ±17 in. (43 cm) (vertically) and ±56 in. (142 cm) (horizontally) of the optimum aiming point at the junction of the body and the turret of a tactical tank. (2) A steady error tone will be transmitted if the gunner is aiming outside the 86 × 284 cm area, but within the established gunner error aiming limits. (3) An alarm tone will be transmitted if the gunner is aiming outside of the established gunner aiming limits. Since the tactical tracker does not make any sound, an on-off switch for the audible aiming error signal will be provided for evaluation.

d. An audible and visible indication must be provided to the gunner for a target hit or miss.

e. The range of all targets, including targets of opportunity, shall be determined automatically and related to the time of flight.

f. The capability of triggering the detectors used in the Multiple Integrated Laser Engagement Simulator (MILES) System shall be included.

g. A means of determining miss distance after a simulated flight must be provided.

h. A capability for an audio-visual recording of the gunner's tracking and the simulated flight must be provided.

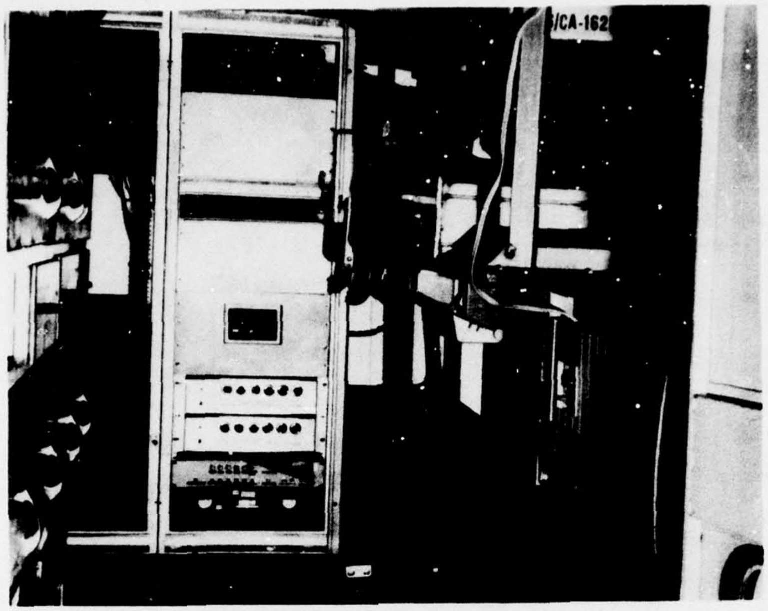
The brassboard model currently built at HDL has met all the functional requirements listed, except for automatic target ranging and compatibility with the MILES System. These features can easily be incorporated into the system, but the schedule has not permitted them to be included in this brassboard model.

3. TECHNICAL APPROACH

3.1 General

The technical approach was severely constrained by the requirement to have operating hardware within 6 months. This aspect of the program demanded that off-the-shelf components be used wherever possible and that procurement and delivery lead times be given prime consideration. Figure 1 is a photograph of the brassboard model training device in front of the van containing the electronics (fig. 2).

Figure 1. Brassboard training device.



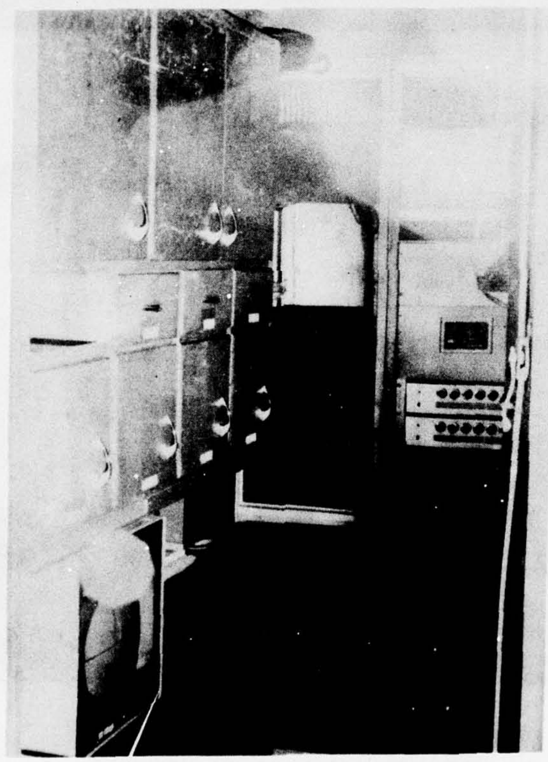


Figure 2. Electronics van.

The target scene is viewed by a color vidicon camera located in the tracker. The simulated missile image is added to the target scene, and the composite picture is displayed on a color kinescope in the tracker. The eyepiece and trigger interface on the brassboard model are identical to the tactical tracker. The gunner views the target scene by looking through the eyepiece at the color kinescope. Simple optics in the eyepiece provide the appearance of distance similar to the view through the tactical tracker.

A continuing problem with all types of training devices for weapons using an optical sight is the lack of a capability to track uncooperative targets to determine the gunner's performance. Solution of this problem would benefit tactical weapons as much as training devices. Investigation has revealed that there are currently no techniques available to track uncooperative targets, but that high-speed digital processing coupled with high-resolution television, radar, or thermal imaging is promising and deserves further research. Since a conditioned target was required for the brassboard model, an infrared (IR) source located on the target was selected as the technical approach with the lowest risk.

Motion of the crosshairs with respect to the target needs to be sensed and acted upon to produce the missile motion and to determine the gunner aiming error. A bright spot of IR light on the target was sensed by a black and white vidicon camera in the tracker, whose field of view is filtered to allow only the IR through. The color vidicon viewing the target scene was filtered to make the IR bright spot on the target invisible to the gunner. Knowledge of the location of the IR spot with respect to the crosshairs and the target range permits computation of the motion of the crosshairs.

Prior to firing, the instructor sets the range and crossing speed of the target using a Teletype (TTY) keyboard. The minicomputer uses the range and crossing speed settings and the sensed location of the IR source to calculate the simulated missile flight and gunner aiming error. At the end of the simulated flight, the minicomputer indicates a hit or miss and displays the miss distance in meters on the teletype.

For the brassboard model, the minicomputer and electronics, the audio-video recorder, and the power supply are placed in a van and connected to the tracker by a cable. Ultimately, all the electronics, except for the power supply and video tape recorder, will be located in the tracker. The power supply can be packaged to look like a spare round connected by a cable to the tracker. The video tape recorder will remain a separate piece of equipment.

The requirement for video tape recording necessitates a television (TV) camera tube, such as a vidicon. Since the audio-video recording must contain the missile image, as well as the terrain and target seen by the gunner, the video used to generate the missile image must be combined with

the vidicon's output video to produce the video tape recording. This combination suggests that the view presented to the gunner during a simulated firing need be only the color kinescope. Several aspects of the training requirement favor this approach.

First, the relative realism of the target scene and the distracting missile should, in the training device, be weighted in favor of a more realistic distraction. Since the system will use a color cathode ray tube (CRT) for the distracting missile image, and since a composite video suitable for presenting the total scene must be generated for the video tape recorder, it is logical to use a color CRT for the gunner's sight.

Second, there is no readily available way to optically combine the target and terrain view and the missile image in a completely realistic fashion. In the actual Dragon engagement, the missile completely obscures that part of the target and terrain scene beyond it. Additive combination in a model optical system will not obscure the scene. Making the missile image brighter than the target scene so that the missile overpowers the scene is not very realistic. It may be possible optically to selectively blank the target and terrain scene beyond the missile and to substitute the missile image, but using a color CRT to portray the whole scene is a simple electronics operation.

Third, the momentary blurring and apparent motion of the target caused by light refraction through the heated air when the side thrusters fire can be easily simulated on a color CRT.

Fourth, distracting effects such as smoke and fog can be readily simulated on the CRT.

Fifth, the view through the night sight, including the missile display, also can be easily incorporated by this technical approach with a CRT.

There is only one technique for generating in full color an image whose size and position are readily controllable, with no development, procurement, or delivery lead time problems. Color kinescope systems are available off the shelf, complete with all the associated electronics for providing their necessary electrode voltages and raster scan. No other readily available means for producing a missile image will accept the three inputs of missile center position, missile size, and side thruster flash command. The missile image itself could be produced by playback of a recording or by a hardware synthesizer. For this brassboard model, a hardware synthesizer is used to generate a colored disc to represent the missile.

A block diagram of the details of the brassboard model is shown in figure 3. Those items within the dotted rectangles are mounted in the tracker on the launcher. The minicomputer and interface hardware, the audio-video recorder, and the system's power supply are connected to the tracker by a cable.

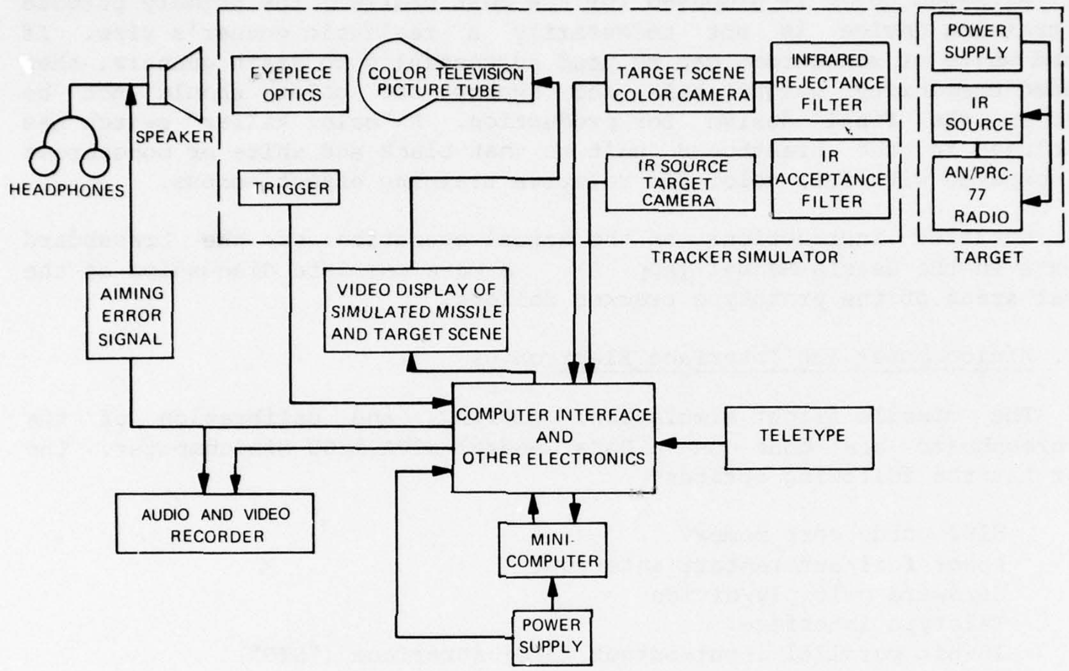


Figure 3. Brassboard system.

A commercial minicomputer is used to calculate the simulated missile flight path; give the missile position, size, and side thruster commands; determine the gunner aiming error; command audible error signals if necessary; and determine if a hit or miss occurred at the target. A microprocessor small enough to be mounted inside the brassboard tracker can be used in the final production design. The schedule has not permitted procurement and programming of a microprocessor for the brassboard model.

Automatic range finding and target crossing speed have not been incorporated into this brassboard model within the schedule. A TTY has been provided for this information to be entered into the minicomputer prior to each shot.

The target crossing speed must be known in order to simulate the flight of a real missile against a crossing target. The real missile lags behind the line of sight defined by the crosshairs when tracking moving

targets. The horizontal distance of lag increases proportionally to increasing crossing speed and decreasing range. In the final production design, the target crossing speed can be determined by using a gyroscope mounted in the tracker simulator or by using an angular readout device built into the bipod.

Although color is proposed for the most realism, the primary purpose of the training device is not necessarily a realistic gunner's view. If black and white or monochrome can be used successfully to train gunners, then the added complexity, weight, bulk, and expense of color should not be included in the final design for production. A "color killer" switch has been included in the brassboard unit so that black and white or monochrome can be compared with full color for relative training effectiveness.

Detailed instructions on the actual operation of the brassboard system are in the User's Manual (app A). A more complete discussion of the technical areas of the prototype tracker follows.

3.2. Minicomputer and Interface Electronics

The missile flight simulation, scoring, and calibration of the Dragon brassboard are done on a Data General NOVA 1200 Minicomputer. The computer has the following options:

8192 words core memory
Power fail/autorestart interrupt
Hardware multiply/divide
Teletype interface
16-bit parallel input-output (I/O) interface ("DIO")

The central processing unit (CPU) is a multiaccumulator processor with 16 levels of maskable interrupts and indexed addressing of all of the memory. An accumulator-to-accumulator addition is executed in 1200 ns. The maximum interrupt latency is 7 μs.

Communication between the computer and the IR tracker, the missile and flame generators, and the two sound generators is done via a multiplexer (DIO controller) of HDL manufacture via the DIO interface.

The DIO controller has the capability of addressing up to 256 12-bit parallel inputs or outputs. The 250 addresses are divided into 16 units (UN00 to UN15) of 16 registers (RG00 to RG15) each. Unit and register assignments and instructions on programming the DIO controller follow. The DIO/DIO controller has the capability of interrupting the CPU at the end of each output or when an input is ready or of requesting an external interrupt.

The DIO interface is mounted in the computer and connected via 16-conductor ribbon cable to the DIO controller, which is mounted in the equipment cabinet directly below the computer.

3.2.1 Input-Output Controller

The DIO controller has the following unit and register assignments:

Unit 00: missile and thruster generator

Missile

Register		
00	-x	
01	-z	
02	x	High order bits
03	x	Low order bits
04	z	High order bits
05	z	Low order bits
06	R	High order bits
07	R	Low order bits

Flame

08	z	Start
09	z	End
10	w	Width
11	y	Start
12	Y	Increment per z step

Coordinates are with respect to the upper left corner of the tracker screen. All words are 12 bits long. A "1" in register 06, bit 04, turns the missile off. A "1" in register 12, bit 04, turns the flame off.

Unit 01: IR beacon

Register		
00	Z	Spot position with respect to upper left corner (vertical)
01	Y	Spot position with respect to upper left corner (horizontal)

Unit 02: audio control words

Register	Bit		
00			Missile audio control
	04		Thruster fire
	05		Hit indication
	06		Miss indication
	07		Launch effects
	10 to 15		Sound magnitude
		00	Maximum sound magnitude
		77	Minimum sound magnitude
01			Aiming error control
	04		Alarm
	05		Error
	10 to 15		Sound frequency
		00	Minimum value of frequency
		77	Maximum value of frequency

The data output to the DIO controller has the format shown in figure 4.

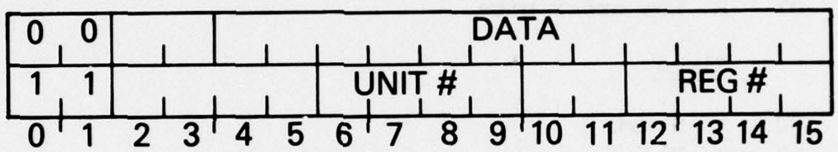


Figure 4. Data output to input-output interface controller.

Bits 0 and 1 are used to generate three different control signals to the controller:

00 UNCLR Clears the controller to UN00, RG00; clears the interrupt request flip-flop circuit, and waits for an external interrupt

11 UNPLS Clears the interrupt request flip-flop and loads the unit select register and the register select counter

00 UNSTRT Clears the interrupt request flip-flop, transmits 12 bits of data from the specified accumulator to the selected unit and register, and clocks the register counter to the next value

All outputs are done by using this:

DOAS (AC), DIO

All inputs are done by using this:

DIA (AC), DIO

3.2.2 Dragon Operating System

The Dragon operating system has four major modes. The power-up (PWRUP) mode is used only to initialize the system at power-on time and to run diagnostic tests. The Dragon start (DGNST), run (RUN), and Dragon end (DGNEN) modes control the Dragon training exercise. The mode of the system is defined by the value of SYSMD, on page 0 of NOVA MEMORY. The following gives a brief description of each of the system operating modes. Detailed information can be obtained from the program listing (app B).

a. Power-up mode.--The power-up mode is initiated automatically when the computer ac line voltage is turned on. If data switches 13, 14, and 15 are set to the octal value 4, 5, 6, or 7, the appropriate test program is started. If the data switches are not set, the power-up mode is completed, and the system is ready to start a training exercise. A description of the test programs follows this description of the power-up mode.

All system parameters are reset during this phase. Also, the operator is queried as to the date and time of day. The time of day is kept in 24-hr time and is automatically incremented by the 60-Hz interrupt line from the video system.

The routines that request the operator to type responses on the TTY keyboard are programmed so that the operator may type only a response of the correct form.

The power-up mode may be initiated from the keyboard at any time by depressing "CTRL" and "P" at the same time.

To start a test program, the operator sets the data switches to the desired test program octal value and types "CTRL" and "P" on the TTY.

Value	Test
4	Beacon (BTEST)
5	Missile (MTEST)
6	Tracker alignment (ALIGN)
7	Sound (SOUND TESTS)

The beacon test routine reads the IR beacon position and prints the coordinates (decimal) in scan lines from the top left corner of the tracker tube. The beacon position is printed on receipt of any character from the keyboard.

Data switch setting	Meaning
0	Return to system
1	Continuous print

The missile test routine displays a missile image at location 128 on the color monitor. The radius squared of the circle is defined by the switch register.

Data switch setting	Meaning
0	Return to system
4 to 15	Radius squared

The alignment routine is used to align the two TV cameras to each other and to measure the displacement between the beacon and the aiming point. The procedure is as follows:

(1) The operator starts "ALIGN." A small circle appears at the center of the screen.

(2) He manually places the crosshairs on the surface of the screen so that they are centered over the small circle.

(3) He pulls the trigger and turns on the beacon.

(4) A larger circle at the beacon position appears on the screen. This circle tracks the beacon position.

(5) The operator aims the tracker at the aiming point. If the circle overlaps the crosshairs, he pulls the trigger, and the program returns control to the system. If the circle does not overlap the crosshairs, he proceeds to step (6).

(6) While continuing to point the tracker at the aiming point, the operator unclamps the black and white camera and moves it so that the circle overlaps the aiming point. He reclamps the camera and goes back to step (5).

(7) Lifting switch 0 after the first trigger, the operator aborts "ALIGN" and returns to the system.

The sound test routine tests both the missile sounds and the aiming error sounds.

Data switch setting	Meaning
0	Return to system
1	Missile sound test
CLR	Aiming error test

Missile test data switch setting	Meaning
4	Thruster sound
5	Hit indication
6	Miss indication
7	Launch
10 to 15	(Value bits)

b. Dragon start mode.--The Dragon start mode initializes the parameters that relate directly to the flight simulation. After initializing the simulation parameters, the values over which the operator has control may be set:

Instructor identification (ID)
Gunner ID
Sky condition
Audio aiming aids (enabled or not enabled)
Missile image (enabled or not enabled)
Hit or miss indication (enabled or not enabled)

The program requests the operator to indicate whether these parameters need to be changed. If they need to be changed, the operator is queried. If they do not, the operator is then requested to enter the target range and speed. After the target range and speed have been enabled, the system enables the gunner's trigger and waits until a firing occurs. The start sequence may be reinitiated at any time by the operator's depressing "CTRL" and "R" on the keyboard.

c. Run mode.--The run mode controls the actual Dragon flight simulation. The run mode is entered when the gunner pulls his trigger.

The interrupt system receives missile and thruster data from the simulator loop and outputs the data to the missile and thruster generator for display on the tracker simulator. The simulator loop also sends thruster, hit, and error information to the interrupt control system. This information is displayed if the appropriate options are enabled. Thruster and hit information is sent through a time of flight servomechanism to delay and attenuate the required sounds as a function of missile range.

The operating system forces the simulator loop to be executed at a 30-Hz rate until the missile is lost from the tracker's field of view or the missile reaches the target plane.

d. Dragon end mode.--The Dragon end mode is entered when the missile is lost from the tracker's field of view or the missile reaches the target plane. This mode always prints out a shot serial number, the date, and the time of day.

If the missile is lost, the flight is terminated, and the range at termination is indicated. If the missile reaches the target plane, the missile position is compared with a rectangle about the aiming point with edges ±1.4 m from the aiming point, top 0.6 m above it, and bottom 0.2 m below it. A hit is indicated as a hit; a miss is indicated by the miss distance from the aiming point.

After scoring information is printed, the Dragon start mode is reinitiated for the next shot.

3.3. Missile Image Simulation

A method has been developed to simulate the Dragon missile image, including thrusters. Using the guidance equations for the real missile, the computer calculates the location (x_o, y_o) of the center of the circle simulating the missile, and it also determines the firing angle of the thruster. The minicomputer does not work fast enough to provide the circle and thruster images. Special high-speed electronic circuitry has been designed to generate the circle and thruster. A digital approach was selected for compatibility with the TV picture tube display of the target scene.

The body of the missile is simulated by using a circle. Two constraints are that the center of the circle can be located anywhere, including out of the target scene, and that the circle can be any size. The equation of a circle is this:

$$r^2 = \left(y - y_o\right)^2 + \left(x - x_o\right)^2 ,$$

where x_o and y_o are the coordinates of the center of the circle and r is the radius.

To determine if a point on the target scene is inside or outside a given circle, the following inequality is used:

$$r^2 - \left(y - y_o\right)^2 > \left(x - x_o\right)^2 .$$

The radius is fixed for each TV frame. Since the TV sweeps each horizontal line in sequence, $(y - y_o)^2$ stays constant on each line. This means that $r^2 - (y - y_o)^2$ need be computed only once each line. This computation could be accomplished during the time required for a horizontal retrace of the TV.

Each line is divided into resolution cells which specify position. The number of resolution cells is determined by the physical characteristics of the TV picture tube. The picture tube used in this system has approximately 256 resolution cells per line, and $(x - x_o)^2$ changes with each new position on each horizontal line. The rapid change in $(x - x_o)^2$ requires that the squares of the x position relative to the end of the line must be computed very quickly.

The final subtraction is $(r^2 - y_o^2) - x_o^2$. A positive number results in 0 for the sign bit, which indicates that the point is inside a circle of radius r centered at x_o, y_o.

A block diagram of the circle generator is shown in figure 5.

At each point on the screen, y_r^2 and x_r^2 represent the square of the y and x distances from the center of the circle. Then

$$r^2 - y_r^2 - x_r^2 \begin{cases} >0, \text{ the point is inside the circle,} \\ <0, \text{ the point is outside the circle,} \\ =0, \text{ the point is on the perimeter.} \end{cases}$$

The most significant bit (MSB) of the difference provides the following information:

$$\text{MSB} = \begin{cases} 1 \rightarrow <0, \text{ the point is outside,} \\ 0 \rightarrow \geq 0, \text{ the point is inside or on the perimeter.} \end{cases}$$

This information is used to switch the video. To avoid noise, the MSB is latched with the horizontal clock.

The missile thruster is simulated by a series of straight lines as shown in figure 6.

The starting point of the thruster is referenced to the center of the circle so that the counters in the circle generator can be used to determine the thruster position. A block diagram of the thruster simulation is shown in figure 7.

Photographs of the circuit boards for the circle and thruster generators are shown in figures 8 and 9.

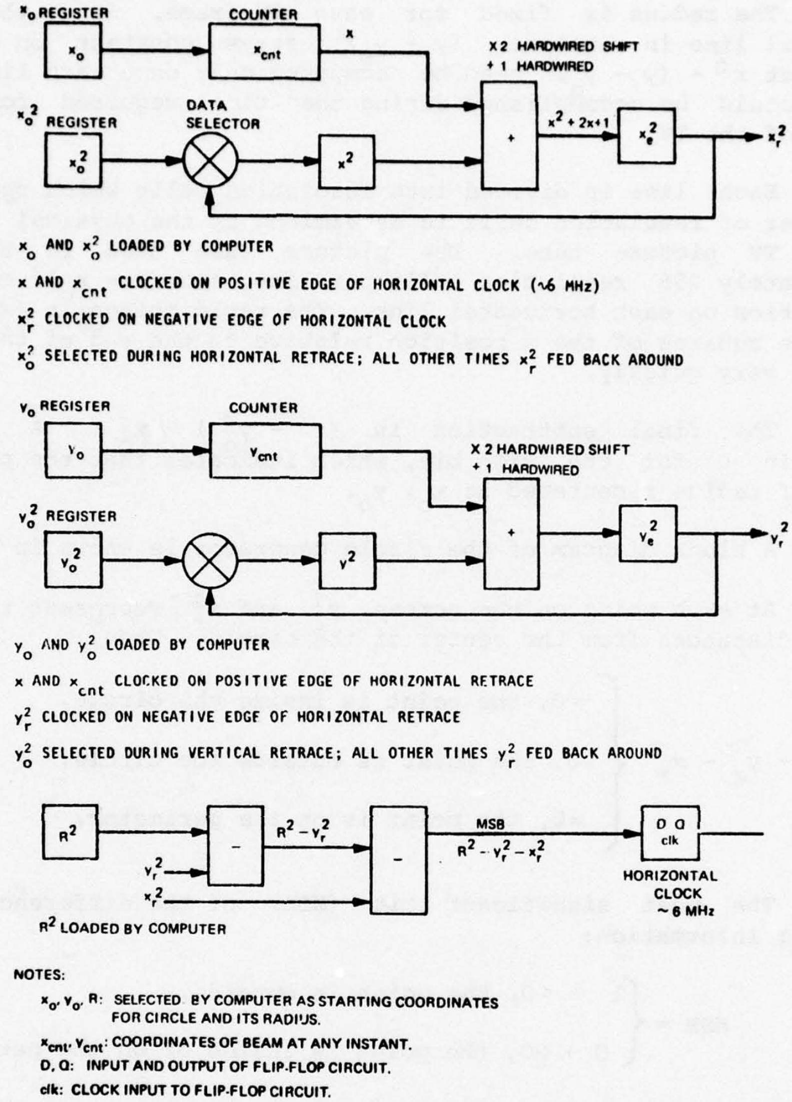


Figure 5. Circle generator.

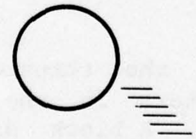


Figure 6. Missile thruster simulation.

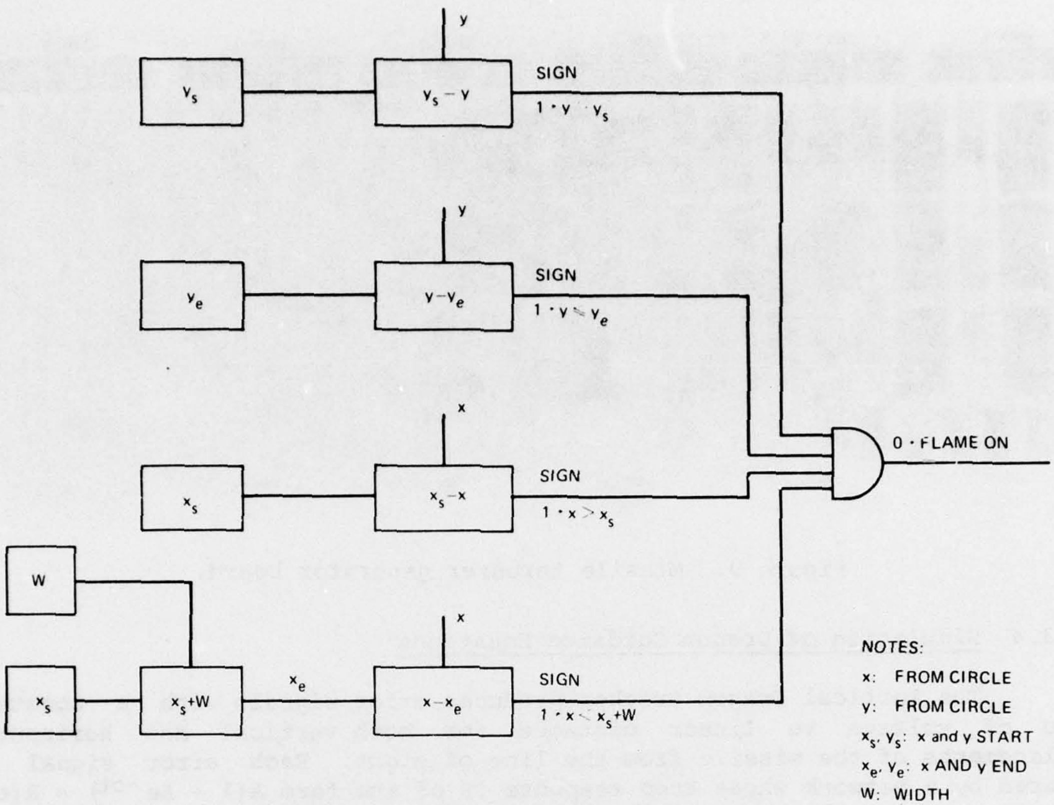


Figure 7. Missile thruster generator.

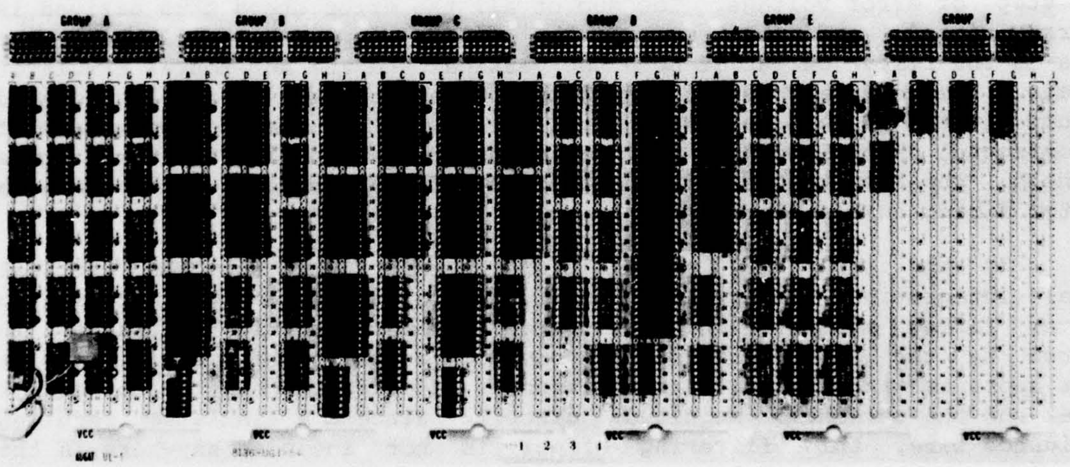


Figure 8. Circle generator board.

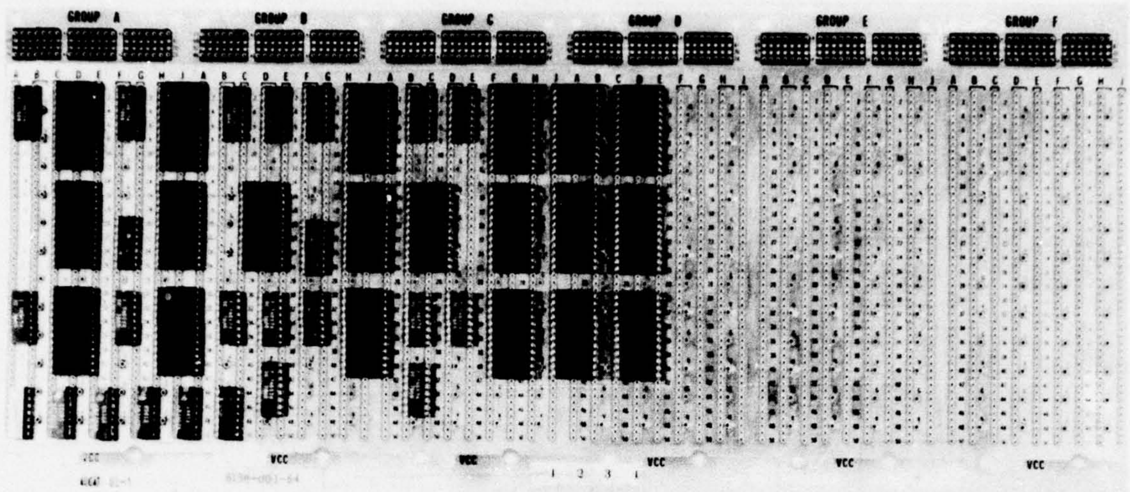


Figure 9. Missile thruster generator board.

3.4 Simulation of Dragon Guidance Equations

The tactical Dragon tracker produces error signals with a constant ratio of voltage to linear distance for both vertical and horizontal displacements of the missile from the line of sight. Each error signal is filtered by a network whose step response is of the form $A(1 + Be^{-ct}) = R(t)$. By taking only the increment (decrement) of error signal at each sampling instant, the simulation produces steps of error voltage $E(Sk) = \varepsilon^{kT} - \varepsilon^{(k-1)T}$, and $AE(Sk)(1 - Be^{-ct})$ is the response, at the kth sample, of the filter to this step of error voltage. The sum of all the error steps thus derived is the error signal, and the sum of the filter responses to all these step inputs is the filter output of both the vertical and the horizontal simulator channels. The vertical channel signal in the real tracker is then integrated and summed with a voltage whose magnitude is proportional to the excess of the horizontal channel signal voltage magnitude above a fixed magnitude threshold. The resultant sum is compared to a fixed threshold to determine a thruster firing enable signal.

In the simulator, a summation is substituted for the vertical channel integration; otherwise, the simulation is identical in determining thruster firing enable. The horizontal error voltage in the tracker is filtered by the guidance wire that conveys signals to the missile, and a filter approximating this filtering action is inserted between the horizontal channel and the threshold magnitude circuit. Since the simulation requires no guidance wire, this filtering effect is not included anywhere in the simulation. Propagation delay introduced by the guidance wire is included in the simulation, as are missile roll rates and missile roll position effects

when the horizontal error voltage is used to determine the thruster firing command in the simulation exactly as it is used in the Dragon missile. The simulation keeps track of which thrusters have been fired and picks the earliest available thruster, exactly matching the real Dragon missile behavior.

The position of a Dragon missile was first simulated by a computer program using Johns Hopkins University Applied Physics Laboratory (APL) computer language prior to doing the program for the NOVA minicomputer. The principles of thruster fire control used in the actual missile are used in the program. Since the simulation must be used in an integer word minicomputer, the variables in the APL program have integer values. Variables are scaled so that sufficient accuracy is obtained. The Dragon brassboard simulator updates data every 1/30 s; therefore, the program computes the position of the missile every 1/30 s. The input data, obtained every 1/30 s, are the number of vertical and horizontal screen scan lines between the line of sight of the weapon and the center of the target. The output is the number of vertical and horizontal screen scan lines between the line of sight and the computed position of the missile.

The simulation begins at trigger pull time of flight (TOF) = 0. Then TOF is incremented in steps of 1/30 s. The missile begins to move at TOF = 23, and the first thruster fires at TOF = 36. In the program, the missile position is computed in an x, y, z coordinate system with the origin at the launch tube, the x axis in meters is measured along the line of sight, the y axis in millimeters is horizontal and positive to the gunner's right, and the z axis in millimeters is vertical and positive in the upward direction.

At each time increment, the position of the missile is updated to allow for the effects of missile inertia and of gravity. If the line of sight has moved with respect to the target, the missile also moves with respect to the line of sight. The new y and z positions of the missile are used by the y filter and the z filter. The y filter computes an angle ϕ indicating the direction in which the thruster should be fired. The z filter numerically integrates a function of the z position. When the integral is greater than a function of the angle ϕ, a flag is set to fire a thruster. A thruster firing is represented by changing the y velocity of the missile by a constant times $\sin \phi$ and by changing the z velocity of the missile by the constant times $\cos \phi$. In the APL program, the process continues until the range of the missile is equal to or greater than the range of the target; but in the minicomputer, the simulation also terminates when the missile has traveled 1100 m or when 30 thrusters have been fired.

The APL function SIGHT is used to generate simulated input data for the APL program. In the minicomputer, these data are received from the IR tracker electronics in the brassboard tracker. For sample input data, the APL program and the minicomputer program give the same results, and these results closely correspond to the known trajectory of the actual missile.

Appendix C contains a block diagram of the APL program and the APL program listing for the guidance equations simulation.

3.5 Infrared Tracker Electronics

The vertical and horizontal coordinates of the IR beacon are measured by the IR tracker, which comprises a TV camera with an IR-sensitive vidicon, a lens system with a 3-deg field of view and an IR selective filter, and a coordinate readout system. The coordinate readout system provides a digital count of (1) the vertical lines in the TV scan between the top of the camera field of view and the IR beacon spot and (2) the horizontal clock positions between the left edge of the camera field of view and the IR beacon spot.

To assure that the IR tracker is producing IR beacon position coordinates, rather than bright sun glints, the IR beacon is made as bright as is reasonably possible, and IR filtering is used at the beacon and the camera. To guard against erroneous inputs to the computer due to occasional sun glints that sometimes are brighter than the beacon, use is made of the fact that the electron beam in a vidicon scans off about 80 percent of the image that the vidicon target has stored on it. Thus, the IR beacon appears only in alternate scans, and the tracker system can distinguish this alternating component of the TV camera's video output from the balance of the scene which is present on every scan, sending a signal to the computer that labels each measurement either good or bad. The IR beacon is pulsed on during every other vertical flyback of the TV scan.

During the scan immediately following this pulse, the coordinate system finds the position of the brightest spot in the scan, stores the (analog) amplitude of the camera video at this point, and remembers the position coordinates of the point. This scan, immediately following the beacon pulse, is called the seek field. During the subsequent scan, called the check field, the (analog) amplitude of the camera video at the remembered position coordinates is compared to the (analog) amplitude stored during the seek field. If the amplitude during the check field is appreciably less than that stored during the seek field, then a GOODATA signal is sent to the computer. If the amplitude at the remembered spot is comparable to the stored amplitude, then the GOODATA signal line to the computer is made to go false, indicating that the last coordinates accompanied by a GOODATA signal should be used.

The tracker video is fed through an electronic switch that removes all synchronized and flyback portions, leaving only responses to the target scene. The output of this switch is fed to the noninverting input of a comparator and to a sampling switch controlled by the output of the comparator so that the sampling switch is closed when the output of the comparator is high. The inverting input of the comparator is connected to the output of the sampling switch; this connection causes the comparator to

go low whenever it exceeds the other input. A storage capacitor and an isolating stage hold the output of the sampling switch at whatever value existed when the switch last opened. Thus, the sampling switch is held open until a video peak appears that is higher than any previous peak. This video peak closes the sampling switch and keeps it closed until the storage capacitor charges up to the new peak, and the video begins to fall back from this new peak. The output of the comparator, labeled "NEWPEAK," is sent to the coordinate logic system and the sampling switch via a gate which is enabled only during the seek field immediately following the IR beacon flash.

During the check field, the sampling switch is disabled so that the storage capacitor retains the highest peak video found during the seek field throughout the check field. An electronic switch, controlled by the seek and check signal, substitutes a fraction of this stored peak value at the input to the comparator during check, and the output of the comparator is then used to detect whether the beacon flash was the point found during the seek field. If the output of the comparator went high during the horizontal scan on which the stored peak was found, then the GOODATA line to the computer is made to go false.

During vertical flyback at the end of the check field, while data are being transferred to the computer, a fourth electronic switch, controlled by the DUMP signal, connects the storage capacitor to ground. This connection clears old data out of the storage capacitor and readies it to search for the highest peak in the next seek field.

3.6 *Audio Simulation*

Five different sounds are needed to meet the system requirements. These sounds can be divided into two groups. In the first group, impulsive sounds simulate (1) the missile launch, (2) the missile thruster firings, and (3) the explosion resulting from a missile impacting the target. An audio tape recording has been made of several real Dragon missile firings. The thruster and explosion sounds have been analyzed and then reproduced by using electronic circuitry. In addition, the thruster and explosion sounds have been delayed proportionally to the distance and the speed of sound to simulate the time lag that occurs in a real missile firing. In the second group, variable tone sounds provide (1) an audible miss tone, which starts when the missile passes the target and decreases in frequency until the computed ground impact of the missile, (2) an error tone, which increases in frequency proportionally to the gunner aiming error, and (3) an alarm tone, which sounds when the gunner exceeds aiming error limits greater than normal gunner errors. The alarm tone is a "whoop" to be distinguished from the error tone. The variable tones also have been generated by using electronic circuitry.

Figure 10 is a block diagram describing the audio simulation portion of the system.

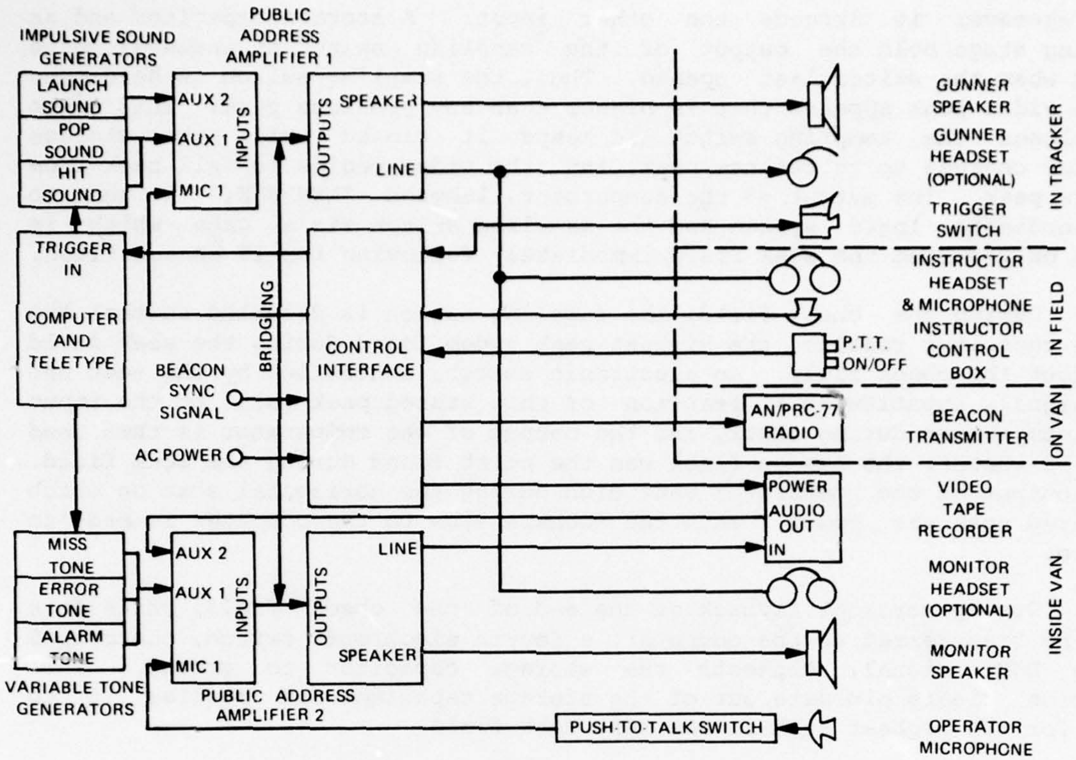


Figure 10. Audio simulation.

3.7 Color Video Circuitry

The target scene is viewed by using a standard commercially available color camera, a Sony DXC-1600. This camera is built with a separate camera head, a camera control unit (CCU), and a power supply, interconnected by appropriate cables. The camera head is mounted in the tracker on a tripod head (used for alignment) and employs a 100-mm lens with a 6-deg field of view. Both the CCU and the power supply are mounted in the electronics rack located in the van. A standard Sony camera head extension cable, coaxial cables, power supply cables, and twisted pair cables interconnect the tracker and the electronics rack.

Signals are extracted from the CCU and are fed to the color TV set mounted on the tracker. The vertical and horizontal signals are used to synchronize all sweep timing circuits in the Dragon training device.

Modifications to a commercially available Sony KV-5000 color TV set permit the set to be used as the target scene display. Direct connections have been made between the CCU and the TV set, so the tuners, I.F., audio,

power supply, color demodulation, and video circuits have been removed. This modification has reduced the physical size of the set to the approximate size of the color CRT. New color video processing boards have been designed to fit the reduced TV set. These boards reconstruct the green signal from the red and blue signals and provide the necessary switching functions to add the thruster and circle images to the video picture. The boards contain driver circuits to couple the TV set to the video tape recorder via coaxial transmission lines.

A heat simulator has been designed and constructed so that the gunner's view of the target scene is disrupted approximately 1/2 s after launch initiation and lasts for 1 s. This disruption simulates the propellant blast during a real launch.

Figure 11 is a block diagram of the complete color system and interconnections.

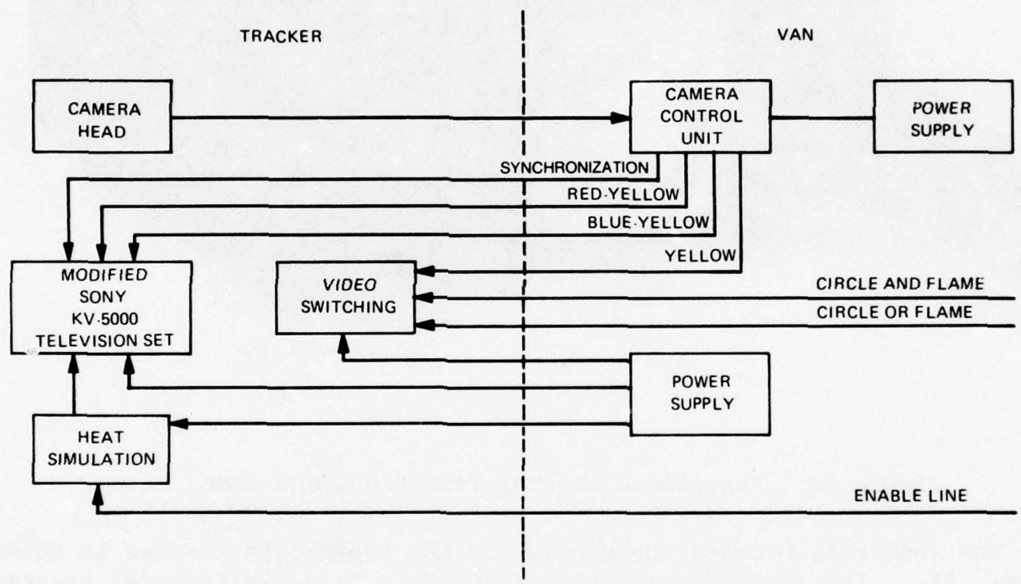


Figure 11. Color video system.

3.8 Mechanical Design of Brassboard Tracker

The mechanical design of the brassboard tracker has been severely constrained by the use of commercially available electronic and mechanical components and by the short time available for mechanical design once the electronic design had been frozen. For this reason, the brassboard tracker has become larger and heavier than originally predicted. Commercial components have been used as normally manufactured, with only the external coverings removed because time has not permitted extensive repackaging.

Figure 12 shows the external configuration of the brassboard tracker. The long lens is on the IR camera, and the short lens is on the color camera. A cooling fan for the cameras and CRT display is on the front of the case between the lenses. This fan was added after the IR camera became overheated during field testing at ambient temperatures of over 96 F without any shade. Selection of a more heat-resistant brand of camera should eliminate the need for forced-air cooling in the future.

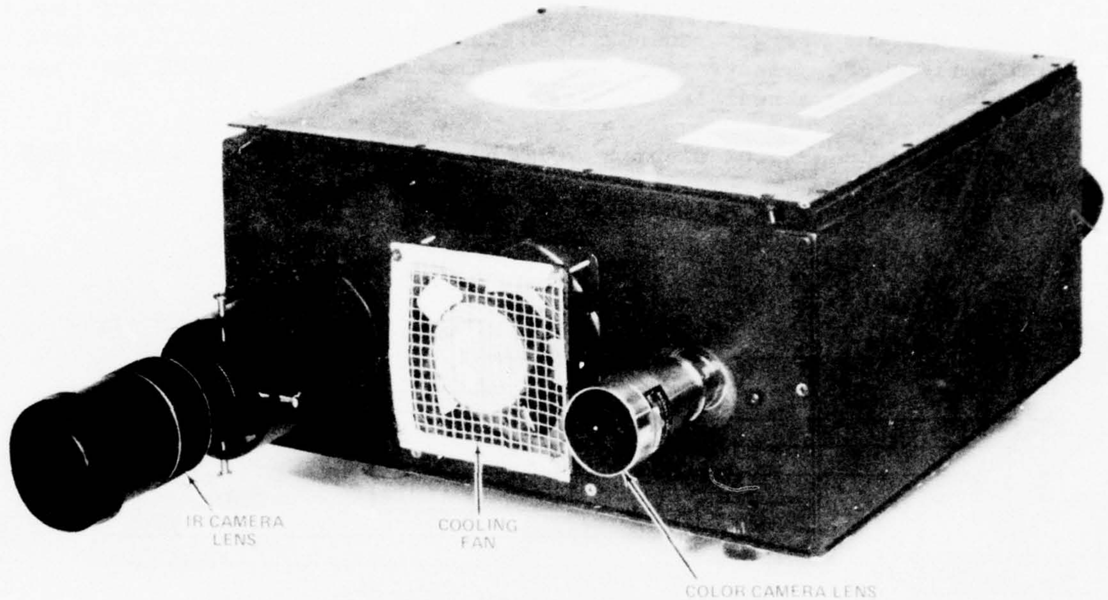


Figure 12. Brassboard tracker from front and side.

The interface between the gunner and the brassboard tracker is shown in figure 13. The eyepiece and trigger assembly from the tactical tracker are used on the brassboard tracker. The handhold interface and mounting pins of the tactical tracker also are used. The center of gravity of the brassboard tracker is positioned so that the gunner has the same weight on his shoulder as when using the tactical system. In spite of the size and weight of the brassboard tracker, the interface specifications between the gunner and the tracker were maintained to enhance realism.

Internal details of the brassboard tracker are shown in figure 14. The color camera, the IR camera, and the CRT display are positioned side by side in the forward position of the tracker. The CRT display is rigidly

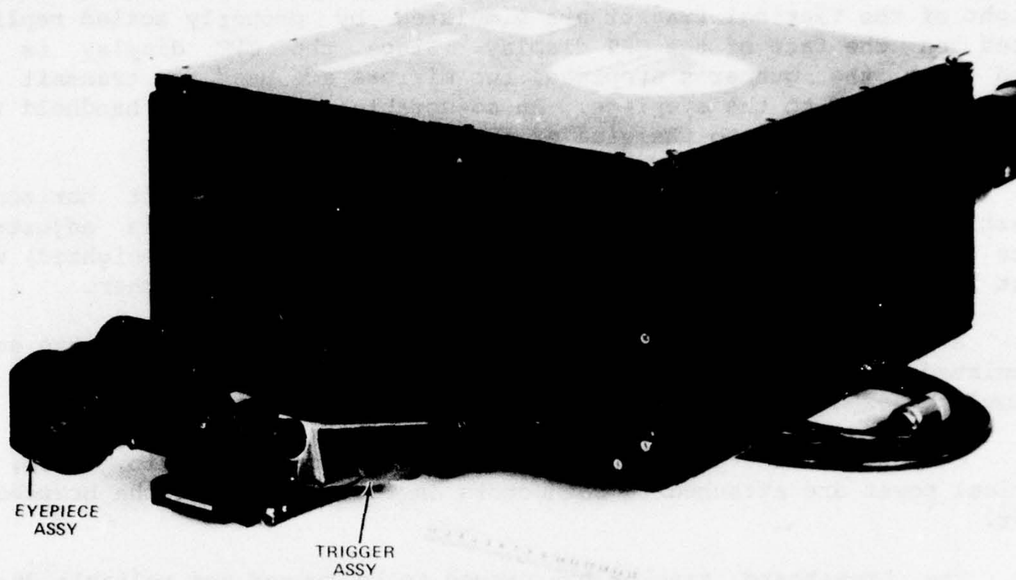


Figure 13. Brassboard tracker from rear and side.

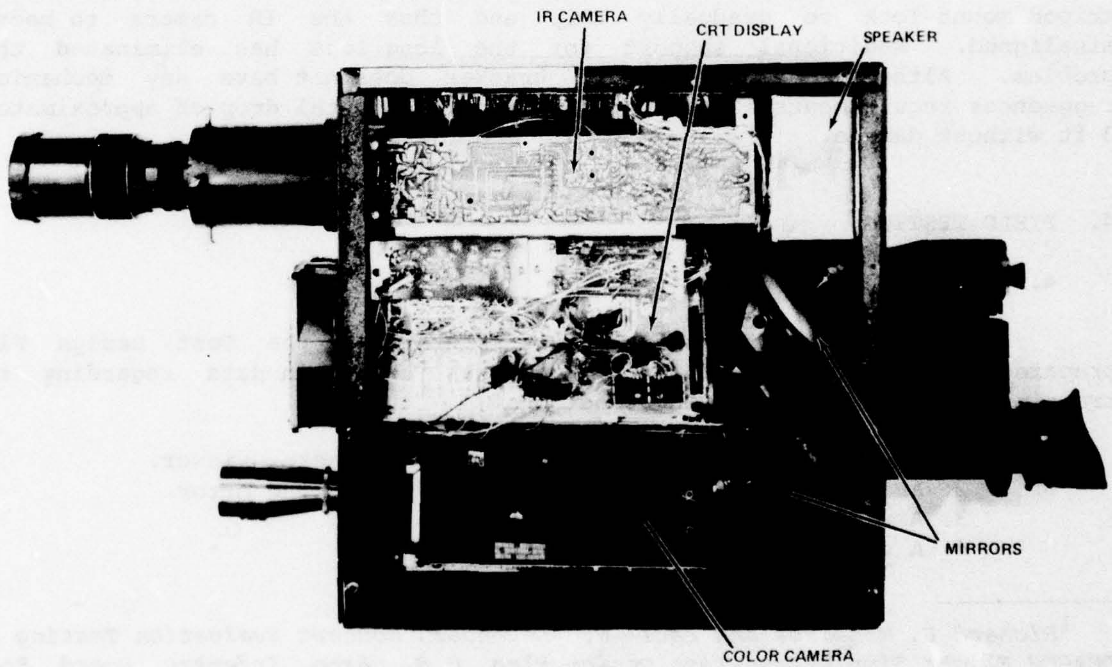


Figure 14. Brassboard tracker with top and sides off.

mounted to the baseplate. The black aiming crosshairs and stadia lines in the sight of the tactical tracker are simulated by properly scaled replicas cemented on the face of the CRT display. Since the CRT display is not aligned with the gunner's eyepiece, two mirrors are used to transmit the display on the CRT to the eyepiece. An adjustable lens in the handhold tube reduces the CRT display to the size of the gunner's eyepiece.

The two cameras mounted on adjustable pedestals permit horizontal and vertical motion and locking in the final position. This adjustment permits the line of sight of the two cameras to be aligned (boresighted) with respect both to the crosshairs on the CRT display and to each other.

A speaker mounted in the corner of the tracker transmits the sound of simulated missile thruster firings, audible tracking error signals, and the simulated explosion of a hit and gives the gunner instructions.

Cables from the equipment in the van that provide audio, video, and electrical power are attached to connectors on the bottom of the brassboard tracker.

The brassboard tracker has proved to be rugged and reliable during field testing. The only modification needed has been additional support for the long IR camera lens. The tripod mount lock proved to be inadequate. Handling of the brassboard tracker during several hours of testing caused the tripod mount lock to gradually slip and thus the IR camera to become misaligned. Additional support for the long lens has eliminated this problem. Although the brassboard tracker does not have any mechanical ruggedness requirements, it has survived one accidental drop of approximately 3 ft without damage.

4. FIELD TESTING

4.1 Test Plan

The objective of the field test as stated in the Test Design Plan prepared by the U.S. Army Infantry Board was "to obtain data regarding the training value of the following functions:

"1. A simulated missile displayed in the tracker viewer.
2. An audible signal indicating gunner tracking error.
3. A visual indication of target hit.
4. A video recording of tracking run."[1]

---

[1]*Richard P. Medeiros and Paul W. Lavendar, Concept Evaluation Testing of DRAGON Flight Simulators--Test Design Plan, U.S. Army Infantry Board, Fort Benning, GA (April 1975).*

The U.S. Army Infantry Board test report[2] contains the official test results and comments relevant to the test objectives. However, several conclusions can be drawn based on experience gained during the test. These conclusions are discussed following the description of the test plan.

The field test began on 7 July 1976 and was completed on 30 July 1976. Table I shows the firing table for each week. Only daylight firings were conducted the first week. All 600-m engagements during the last 3 weeks were conducted at night with a xenon searchlight for target illumination.

TABLE I. FIRING SCHEME

Engagement	Speed (km/hr)	Vehicle travel	Position	Range (m)	Test day
1	17	Right to left	Flanking	200	First
2	17	Left to right	Flanking	200	First
3	35	Right to left	Flanking	200	First
4	35	Left to right	Oblique	200 to 300	First
5	17	Right to left	Oblique	300 to 200	First
6	17	Left to right	Flanking	400	Second
7	35	Right to left	Flanking	400	Second
8	35	Left to right	Oblique	400 to 500	Second
9	35	Right to left	Oblique	500 to 400	Second
10	17	Left to right	Oblique	400 to 500	Second
11	17	Right to left	Flanking	600	Third
12	17	Left to right	Flanking	600	Third
13	35	Right to left	Flanking	600	Third
14	35	Left to right	Oblique	600 to 700	Third
15	17	Right to left	Oblique	700 to 600	Third
16	17	Left to right	Flanking	1000	Fourth
17	35	Right to left	Flanking	1000	Fourth
18	35	Left to right	Oblique	1000 to 800	Fourth
19	35	Right to left	Oblique	800 to 1000	Fourth
20	17	Left to right	Oblique	1000 to 800	Fourth

The test plan called for each gunner to fire 80 engagements consisting of the 20 engagements in the firing scheme shown in table I in each of four different system configurations:

[2]*Richard P. Medeiros and Paul W. Lavendar, Concept Evaluation Testing of DRAGON Flight Simulators--Test Report, U.S. Army Infantry Board, Fort Benning, GA (June 1976).*

1. Configuration 1 was the baseline system for evaluating selected functions. The complete system was operable.

2. Configuration 2 was the same as configuration 1, except that the missile display was deleted.

3. Configuration 3 was the same as configuration 1, except that the missile display and target hit indication were deleted.

4. Configuration 4 was the same as configuration 1, except that the aiming error tones were deleted.

Each gunner fired his engagements in groups of five. On every test day, each gunner fired five engagements from the firing scheme (table I) in each of the four configurations on the HDL and Martin-Marietta Corp. systems. Testing for the day was completed when all the test soldiers had completed the five engagements on both systems in all four configurations. With four gunners and no interruptions, 1 day of testing could be completed in approximately 4 hr.

Figure 15 shows the test range layout. Oblique firings at 200, 400, and 600 m were conducted with the target vehicle following a track between the western orange flanking panel and the most southern yellow panel. For 1000-m oblique firings, the target vehicle track was between the western orange flanking panel and the most northern yellow panel. Flanking firings at all ranges had the target vehicle track between the orange panels.

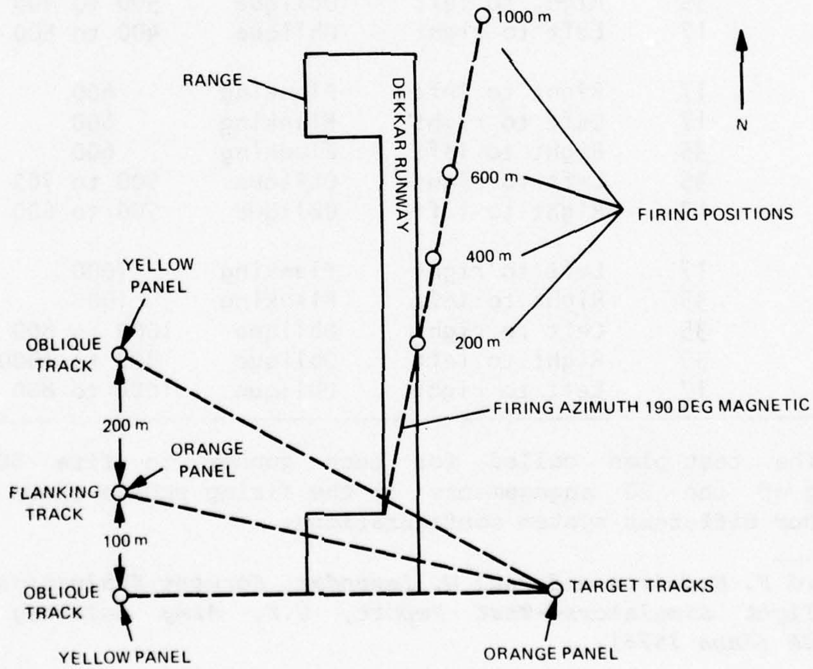


Figure 15. Test range layout.

4.2 Problems and Corrective Action

Several problems arose during the field test. Some of these problems were solved during the field test whereas others will require future hardware modification. Despite problems with the IR source during the test, the testing was completed on schedule.

Infrared source.--During checkout of the system the week prior to the field test, the Strobolume IR source was working intermittently. A replacement could not be obtained, and an attempt was made to use the standard M70 TOW/Dragon target board with its IR source. This worked well during the first day of testing when the sky was overcast. The second day was sunny, and the M70 target board IR source was not bright enough to be seen against the background IR level created by the sun. At this time, a change was made to an IR source consisting of an aircraft landing light with an IR filter in front of it. This approach worked well during the remainder of the test, but the light used had too narrow a beam to handle the complete target crossing range. This problem was overcome by verbally telling the gunner when the system was ready to engage. The light had a beam approximately 50 deg wide compared to the approximately 70-deg angle needed to encompass the entire target crossing range. Future IR sources can be made omnidirectional to eliminate this problem of a narrow beam. The Strobolume approach worked well during the brief period that the Strobolume itself was working. Checking to determine that the real source is being seen instead of sun glints, etc., is a sound approach that should be used in the future.

Infrared camera lens support.--Boresight alignment of the two cameras gradually changed with time and handling. The support for the IR TV camera slipped despite having been tightened as much as possible. An additional support was fabricated to support the camera lens. This support eliminated this problem of slippage.

Target scene resolution.--Most of the test soldiers commented that the target scene appeared blurred compared to the real tracker scene. This problem of blurring was caused by lack of resolution of the TV picture tube. Schedule constraints forced the use of a consumer type of color TV picture tube which did not have high resolution. Higher resolution picture tubes are available, and a system that provides resolution as good as the human eye should be included in any future effort.

Night firings.--After the system was delivered to Fort Benning and field testing started, the U.S. Army Infantry Board fired at night at the range of 600 m using a xenon searchlight to illuminate the target. The HDL system was not designed to work at low light levels. Consequently, the IR source on the target was the only thing visible in the target scene during the night firings. Special low light level TV cameras are available. These cameras can be incorporated into the HDL system if a night training requirement using the daylight tracker is anticipated.

4.3 Test Summary

The system worked well despite problems with the IR source. The system was capable of performing under all conditions of the test plan. Some conclusions based on observations during the field test follow.

a. The test gunners liked the red missile image, and the thrusters were plainly visible. The missile image gave the gunners practice in ignoring the missile and a chance to explore the capabilities of the Dragon missile system when tracking moving targets. For maximum realism, the system used the same guidance equations as the tactical missile. The hit indication has training value because it provides psychological satisfaction to the gunners and gives them immediate feedback of their performance.

b. The aiming error tone may have value for beginning gunners. But since the tactical tracker makes no sound, reliance on techniques learned by using an aiming error signal will not help develop the tracking techniques needed for the tactical tracker. Therefore, the aiming error tone should probably not be included in future designs because of the negative training that may result.

c. No negative comments concerning the missile launch sound and thruster pops were noted from the gunners. Since these sounds increase the realism of the simulation, they should be included in future designs.

d. Video tape recording is a valuable training aid. Many of the gunners reviewed their previous shots and were able to improve their performance by correcting some of the problems noticed in the video tape replay.

5. CONCLUSIONS

5.1 Current Program

The brassboard model worked well during the month of field testing at Fort Benning, once the initial start-up problems were solved. The technical approach was proven to be feasible. The realism of the simulation was appreciated by the test gunners. The aiming error tone was not considered an advantage by the gunners because they believed that it might train other gunners to depend upon something that is not present in the tactical tracker. Video tape recording was considered a valuable training aid by the gunners. They reviewed their previous shots and were able to improve their performance by correcting their errors. Despite some problems, the system demonstrated that a realistic simulation of Dragon missile firings with videotape recording should prove to be a valuable training system.

5.2 Future Effort

The approximate cost and schedule to develop two Advanced Development prototypes using this concept were estimated. These prototypes would use two IR sources on the target for automatic tracking and ranging. It was estimated that $1 million in funding and 12 to 15 months of effort would be required to deliver the two prototypes for Advanced Development testing. The primary technical challenge is to develop and fabricate a color CRT and camera system that is much smaller and that has higher resolution than existing commerical systems. Initiation of an Advanced Development program awaits completion of requirements defining the specific characteristics for the two prototypes.

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APPENDIX A.--USER'S MANUAL: DRAGON FLIGHT SIMULATOR (BRASSBOARD)

CONTENTS

APPENDIX A

FIGURES

A-1. INTRODUCTION

This manual applies to the Brassboard Dragon Flight Simulator produced for the Project Manager for Training Devices (PM-TRADE) by the Harry Diamond Laboratories (HDL).

Material is presented dealing with system description, operating instruction, and maintenance. Because the brassboard system is a development prototype, operation and maintenance should be under the direct supervision of personnel from HDL.

A-2. SYSTEM DESCRIPTION

This Brassboard Dragon Flight Simulator consists of two groups of equipment: (1) equipment on loan from HDL for the field trials and (2) equipment built for, purchased for, or borrowed from PM-TRADE.

a. *On loan from HDL*

1. Step van
2. Two television (TV) monitors, CONRAC SNA17 and Shibaden VM-901
3. One modified Strobolume, General Radio 1540-P4
4. One low voltage power supply, Dynage KH-12-12
5. One equipment cabinet

b. Owned by PM-TRADE

1. Modified Dragon Tracker and Launcher Assembly
2. Miscellaneous parts of two color TV sets, SONY KV-5000
3. Miscellaneous parts of two color TV cameras, SONY DXC-1600
4. Miscellaneous parts of two silicon target black and white TV cameras, RCA TC 1005
5. Two low voltage power supplies, Powermate OEM-18-D and PXS-D-5V
6. One teletype (TTY), Teletype Corp. model 3320 3JC

7. One minicomputer, NOVA 1200

8. One video tape recorder, SONY AV-3600

A-2.1 Physical Layout

For the field trials, the heart of the simulator is mounted in an equipment cabinet in a step van with the tracker-launcher and generator power supply nearby. The standard M70 TOW/Dragon target board is used with the HDL infrared (IR) source clamped onto it. Figure A-1 shows a typical field arrangement.

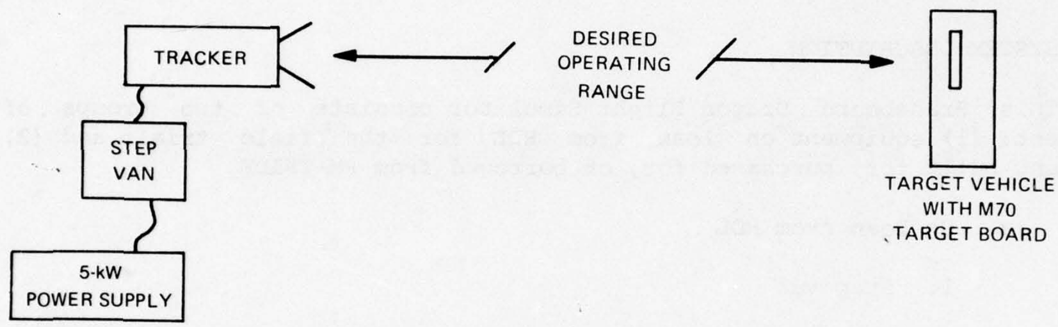

Figure A-1. Typical brassboard Dragon flight simulator test setup.

If used, the generator power supply is located to minimize noise at the tracker-launcher location. The equipment in the van is arranged as shown in figure A-2.

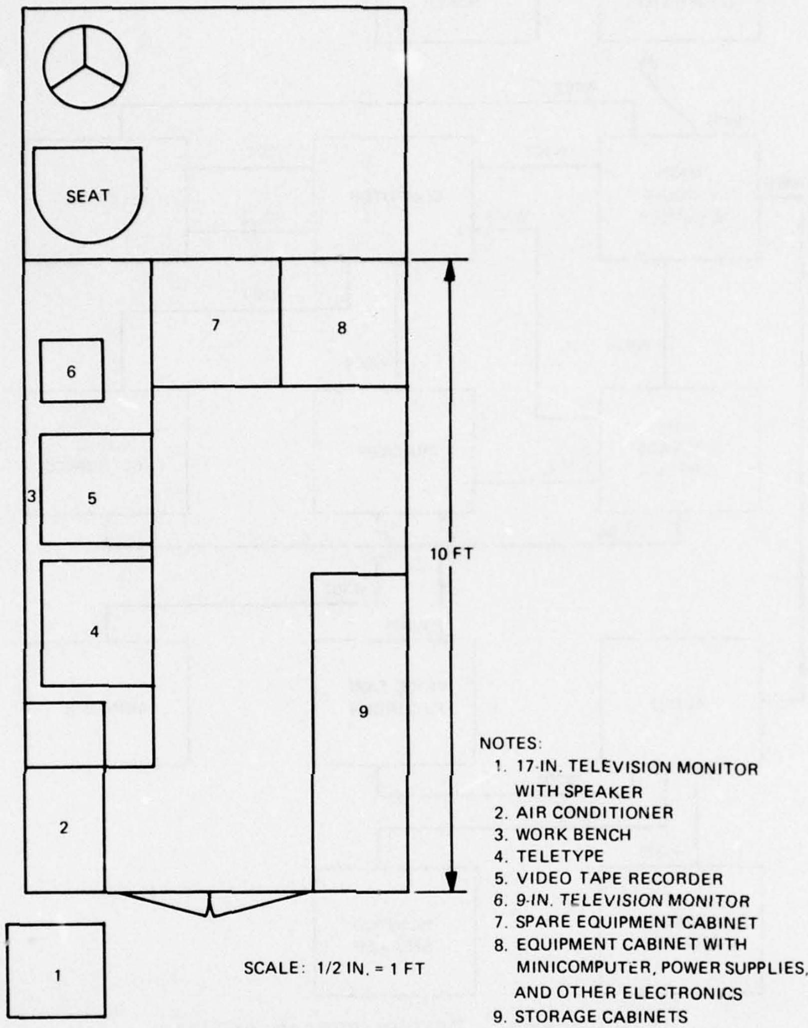

Figure A-2. Brassboard Dragon flight simulator van configuration.

A-2.2 Electrical Networks

Figure A-3 shows the major interconnecting cables in the system. Table A-I lists the functions of the cables. No cables are expected to be connected or disconnected after checkout at HDL prior to delivery, except for the primary power connection.

APPENDIX A

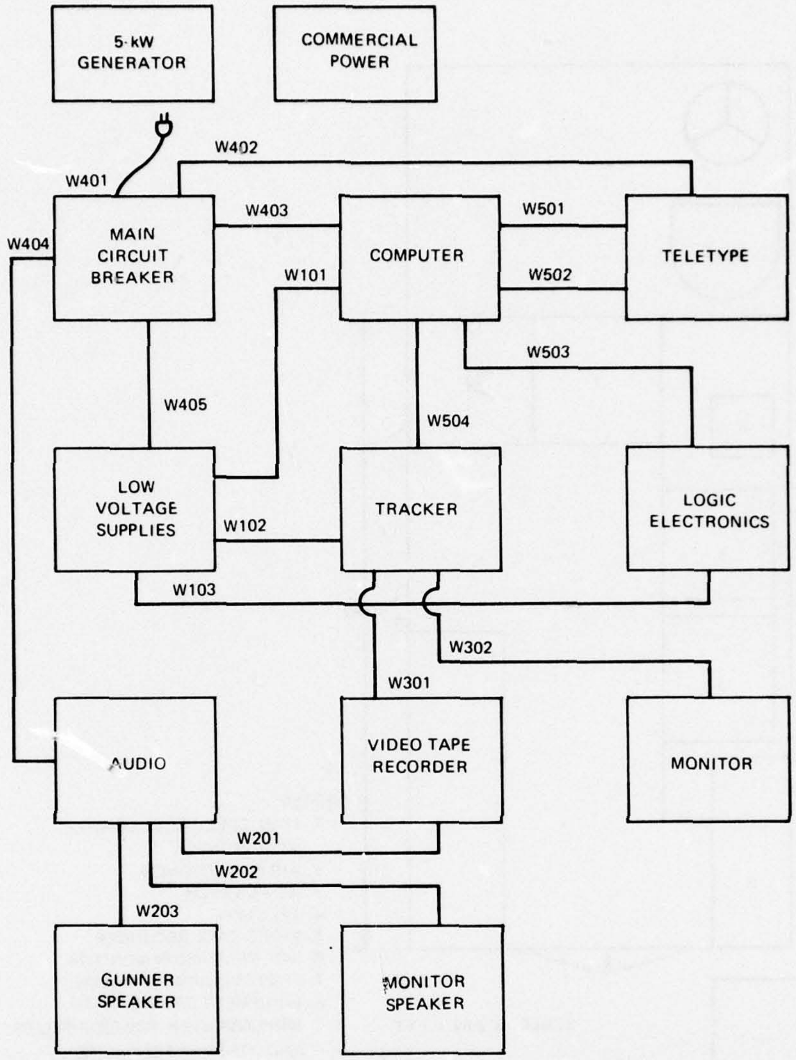

Figure A-3. Dragon system cabling.

TABLE A-1. CABLE IDENTIFICATION

Cable	Function
W101-103	Low voltage power
W201-203	Audio
W301-302	Video
W401-405	Alternating current power
W501-503	Digital data

A-2.3 Theory of Operation

This section describes the theory of operation in very broad terms as an aid to operation of the simulator.

A-2.3.1 General

The simulator (fig. A-4) is designed to present the gunner with as realistic as possible a simulated Dragon missile engagement using real targets in the field. Selected features can be included or deleted from the simulation to evaluate their effect on the gunner's performance. Simulation of the missile launch blast, recoil, and sound is part of another simulator which is not part of this effort.

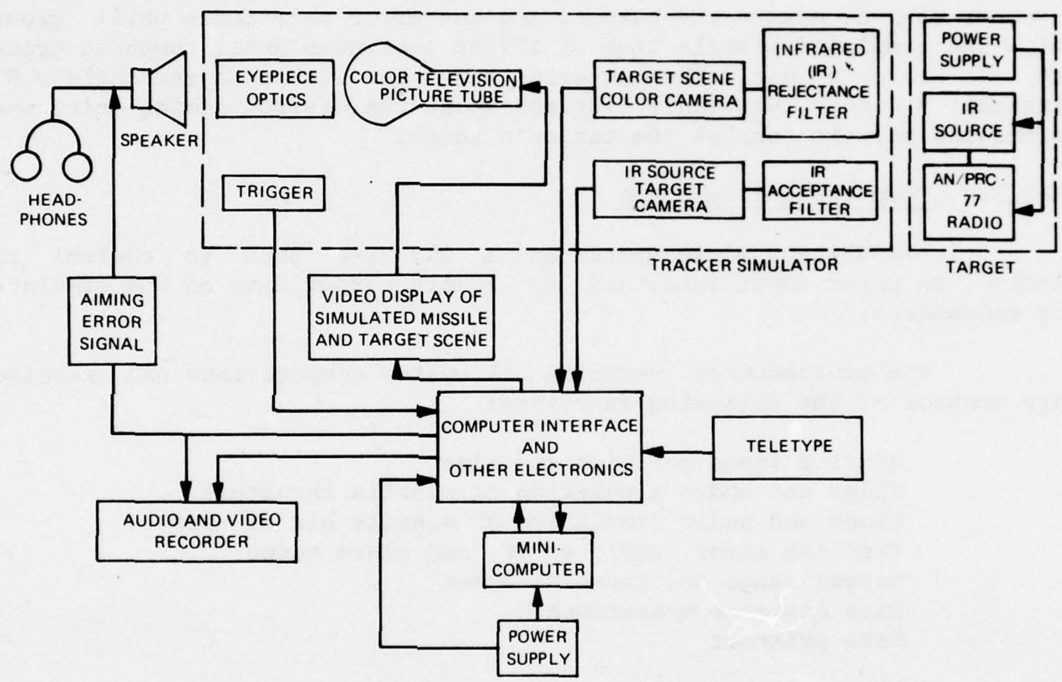

Figure A-4. Dragon system.

A-2.3.2 Tracker-Launcher

The tracker-launcher assembly consists of an empty (expended) launcher tube and bipod fitted with a Dragon tracker simulator. This simulator uses the eyepiece and trigger assemblies from the real tracker to provide the proper interface between the gunner and the tracker. The remainder of the tracker simulator contains a color TV picture tube, a color TV camera, and a black and white TV camera.

When sighting, the gunner sees the target, the crosshairs, and the stadia lines as with the real Dragon system. When the trigger is

depressed, a simulated missile flight begins after a wait for the 0.533-s delay that is present with the real Dragon system. A circular spot, scaled to missile size as a function of range, appears in the gunner's field of view at the same time and in the same location as for the real missile. After the minimum missile command delay, commands are given by the minicomputer to control the position of the missile image using the actual guidance equations and the gunner's aiming motions. The gunner sees flashes of light representing thruster firings at the correct roll position. As the missile image flies downrange, its size diminishes.

When a hit is scored, the gunner sees a flash of light filling his field of view as a simulated explosion. When a miss occurs, the missile spot disappears when it reaches the plane of the target scene, indicating to the gunner that he missed the target, and the error tone fades until ground impact. The simulated missile time of flight continues until computed ground impact. To score a hit, the missile must be within a rectangle 2.8 m (horizontal) $\times$ 0.86 m (vertical) centered about the desired aiming point when the simulated missile reaches the target's range.

A-2.3.3 Computer and Teletype

A NOVA 1200 minicomputer and a TTY are used to control the simulation, to enter input data, and to record output data on the simulated Dragon engagement.

The minicomputer performs all system computations and exercises primary control of the following functions:

- Missile image position and size
- Video and audio simulation of missile thrusters
- Video and audio simulation of missile hit or miss
- Tracking error, audio error, and alarm tones
- Target range and crossing speed
- Miss distance measurement
- Data printout

A-2.3.4 Video Tape Recorder and Monitor

The video tape recorder is a reel-to-reel type which has the capability of "freezing" the video picture. The monitor can display either the target scene or the recorded simulated Dragon engagement for playback.

A-2.3.5 Sound System

The sound system (fig. A-5) consists of the sound and tone generators, two amplifiers, a loudspeaker mounted on the TV monitor, a small speaker mounted in the tracker simulator near the gunner's ear, connections for a gunner's optional headset and an observer's headset, an instructor's headset with both a microphone and a push-to-talk switch, and a connection for the audio channel of the video tape recorder.

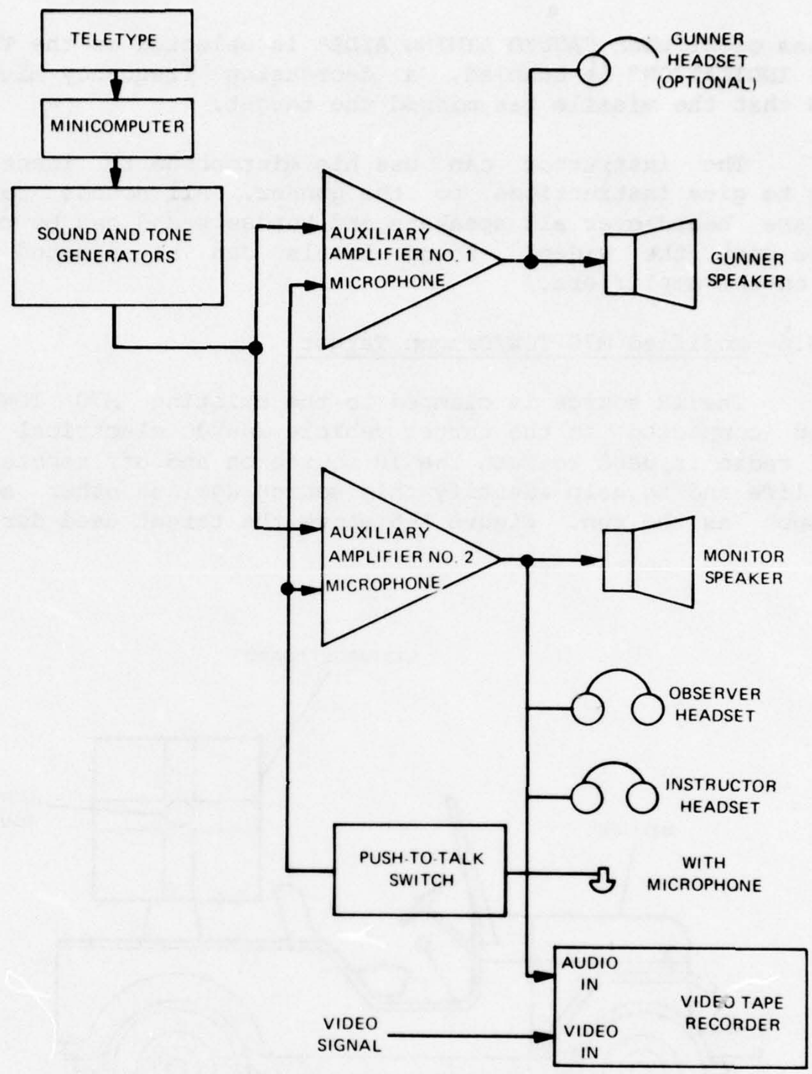

Figure A-5. Sound system.

Under control of the minicomputer, the sound generators produce a "pop" at each simulated thruster firing and a simulated explosion when a hit is scored. These sounds are delayed and attenuated as a function of the range at which they occur. The thruster and simulated explosion sounds occur whenever the missile image and hit indication are enabled via the TTY.

An error tone is generated whose frequency is proportional to the gunner's aiming error. This tone changes to a "whoop" alarm tone when the gunner exceeds the established 3-sigma gunner's aiming error limits.

APPENDIX A

These tones occur when "AUDIO AIMING AIDS" is selected on the TTY. When the "HIT/MISS INDICATION" is enabled, a decreasing frequency miss tone audibly indicates that the missile has missed the target.

The instructor can use his microphone to identify the shot number or to give instructions to the gunner. All sounds, tones, and voice comments are heard over all speakers and headsets and can be recorded on the video tape with the video. Sound levels can be adjusted with the level controls on the amplifiers.

A-2.3.6 Modified M70 TOW/Dragon Target

The IR source is clamped to the existing M70 TOW/Dragon target board and connected to the target vehicle 24-Vdc electrical system. One AN/PRC-77 radio is used to turn the IR source on and off remotely to conserve the bulb life and to help identify this source against other sources of IR energy such as the sun. Figure A-6 shows the target used during the field tests.

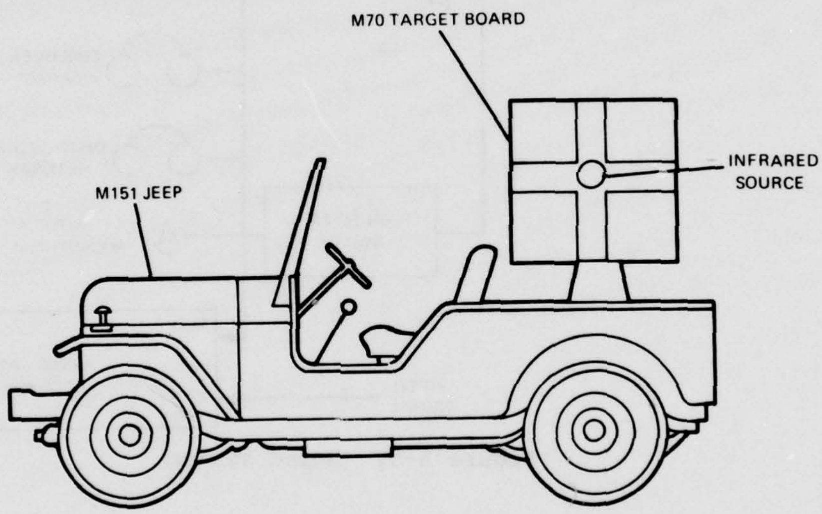

Figure A-6. Modified TOW/Dragon target.

A-3. OPERATION

This section presents the operating instructions for the simulator as configured for the field trials at Fort Benning, GA. These instructions assume the participation of personnel qualified as indicated.

Gunner: trainee who has received preliminary classroom instructions on the Dragon system

Instructor: qualified Dragon instructor with additional instruction by HDL on the simulator system

Test engineering support: HDL personnel

Target operator: operator who is qualified to operate the target vehicle with the TOW/Dragon target mounted and who has received additional instruction from HDL

A-3.1 Setup

These instructions pertain to this van-mounted simulator.

A-3.1.1 Site Selection

The operating site should provide a clear line of sight at ground level from the tracker-launcher to the target. If brush or other obstacles exist at low level, it might be necessary to have the tracker-launcher (truck bed, etc.) elevated to achieve a clear line of sight to the target.

When selecting the site, consideration should be given also to the sun angles that will exist during use, the room available to the target vehicle when a moving target is to be used, and the availability of 115-V, 60-Hz power at the van location. The van can be operated by a generator greater than 5 kW, if necessary. Considering all the pertinent factors, the range used should be approximately 1000 × 300 m and oriented so that the tracker-launcher and van are at the south end of the long dimension. A west or an east orientation is satisfactory as long as the gunner does not look into the sun. When a moving target capability is desired at all ranges, the terrain should be relatively smooth so as not to impede the target vehicle.

A-3.1.2 Emplacement and Preparation for Use

The van should be parked with the rear doors facing downrange and adjacent to the desired gunner's position. The van must be in the parking gear, and the parking brake must be set. The van operator should perform the following operations:

1. Open the rear double doors.

2. Remove the tracker-launcher from the van and place it at a convenient location within the 30-ft length of connecting cable. Use the rest tripod to support the aft end of the launch tube.

3. Check that the main circuit breaker is in the off position.

4. Check that the target electronics box is connected to the target vehicle 24-Vdc system and that the IR source and AN/PRC-77 radio are in place.

5. Connect the primary power cable to the range 115-Vac power supply or to the portable generator, whichever is to be used.

The system is now ready for checkout.

A-3.2 System Checkout

These procedures should be followed daily prior to the start of each testing session. This checkout procedure assumes that the equipment is emplaced and prepared for use (sect. A-3.1.2).

A-3.2.1 Power Application

Power is applied by the following steps in the order indicated:

1. When a portable generator is used, start the engine and bring it on line in accordance with applicable instructions.

2. Operate the main power breaker to the on position.

Power is now applied to the computational and monitor systems, and the system is now ready for preoperational checks.

A-3.2.2 Preoperational Checks

In preparation for preoperational checks, the target vehicle should be positioned at a known range between 65 and 1000 m; 500 m is suggested. The target board should be approximately perpendicular to the line of sight of the tracker-launcher.

The rest tripod should be used to aim the tracker-launcher at the target board so that the crosshairs match the crosshairs on the target board. The crosshairs on the TV monitors should line up with the target board crosshairs. (If not, a boresight error exists; HDL personnel will fix it.)

Then the TTY operator enters the information that it requests. The TTY prints the header (request for information) for each line and then pauses awaiting the manual entry. After providing the information requested, the operator presses the RETURN key. For questions requiring a "yes" or "no" answer, the TTY proceeds automatically without a need for the operator to press the RETURN key. After each correct entry of "yes" or "no" or when the

RETURN key is operated, the TTY spaces one line, prints the next header, and pauses awaiting manual entry. This process is repeated until after the target elevation is entered and the RETURN key is pressed. At that time, the TTY spaces one line and pauses for completion of the simulated firing. After the first run, if the previously entered information (such as instructor identification or gunner identification) remains unchanged, the operator answers only "yes" or "no" to the TTY question, "NEW PARAMETERS (Y OR N)?" The TTY then prints all the information through the "HIT/MISS INDICATION?" question without further manual input. For each run, the operator must manually enter the target range, crossing speed, and elevation. When he makes an error, he must press the CONTROL and R keys together. The TTY then starts at the beginning, and the operator must enter all the data again.

The operator must perform the following functions:

1. At the start of the day after the power has first been applied to the system, check that the TTY reads "DATE" (MM/DD/YY).

2. Enter the month, day, and year as, for example, "5/1/78," and press the RETURN key. The TTY will print "TIME" (HH: MM: SS).

3. Enter the time of day (hour, minute, and second) as, for example, "8:30:00," and press the RETURN key. The TTY will print "NEW PARAMETERS (Y OR N)?"

4. If you make an error in entering the date or time of day, press the CONTROL and the P keys together. The TTY will then ask for the date and time again. The minicomputer automatically keeps track of the date and time of day after the initial entry as long as the power remains on. Enter "N" for no. The TTY will return automatically and print "INSTRUCTOR ID."

5. Enter "TEST" and press the RETURN key. The TTY will print "GUNNER ID."

6. Enter "TEST" and press the RETURN key. The TTY will print "CLEAR SKY (Y OR N)?"

7. Enter "Y" or "N" for yes or no. The TTY will print "AUDIO AIMING AIDS (Y OR N)?"

8. Enter "N." The TTY will print "MISSILE IMAGE ENABLED (Y OR N)?"

9. Enter "N." The TTY will print "HIT/MISS INDICATION (Y OR N)?"

10. Enter "N." The TTY will print "TARGET RANGE (M)?"

11. Enter the target range in meters and press the RETURN key. The TTY will print "TARGET CROSSING SPEED (KPH)?"

12. Enter the target crossing speed in kilometers per hour and press the RETURN key. Use "+" for a target moving from left to right and "-" for a target moving from right to left. The TTY will print "TARGET ELEVATION (M)?"

13. Enter the target elevation in meters with respect to the tracker-launcher location. Use "+" for a higher and "-" for a lower elevation. Enter "0" if the elevation is unknown. Press the RETURN key. The TTY will pause until the shot is completed.

14. Turn on the switch to start the AN/PRC-77 radio and video tape recorder.

15. Operate the trigger without moving the tracker, and observe the tracker, the TV monitor, and the sound system. There should be no missile image, thrusters, or simulated explosion visible. No audible error tones, thruster firings, or explosion sound should come from the sound system. A hit should occur. After the hit, the TTY will print, "SHOT NO. XX HIT ON (DATE) AT (TIME)."

16. Turn off the radio and video tape recorder switch at the van until the next shot is readied.

17. The TTY will have printed *"NEW PARAMETERS (Y OR N)?"* after printing the hit indication.

18. Enter "N." Repeat steps 5 to 14, but enter "Y" instead of "N" in steps 7, 8, and 9.

19. Use the microphone to enter shot No. XX + 1.

20. Check that the tracker is aimed at the target, and operate the trigger without moving the tracker. Observe the tracker, the TV monitor, and the sound system. The missile image should appear and move like the real Dragon missile. Simulated thruster firings should occur with their sounds. No audible aiming error sounds should be heard. A simulated explosion with its sound should occur at the target. After the hit, the TTY will print "SHOT NO. XX+1 HIT ON (DATE) (TIME)."

21. Turn off the radio and video tape recorder switch.

22. Rewind the video tape recorder to the starting point and play back the tape. Note the quality of the playback, both video and audio.

23. The TTY will have printed "NEW PARAMETERS (Y OR N)?" after printing the hit indication.

24. Enter "Y." The TTY will print all the previous answer data through "HIT/MISS INDICATION (Y OR N)?"

25. Enter the target range, crossing speed, and elevation as in steps 11, 12, and 13.

26. Remove the tracker-launcher from rest and tell a gunner to assume the firing position.

27. Turn on the radio and video tape recorder switch.

28. Turn on the video tape recorder and use the microphone to enter shot No. XX + 2.

29. The gunner should aim at the target and fire in the normal fashion; but about 1 to 2 s after firing, the gunner should induce a miss by aiming above the target and to the right or left approximately 5 to 10 m. Instruct the gunner to shift the aiming point smoothly and to hold steady at the desired aiming error. Observe that the monitor indicates a miss, the audible error tone goes through the warning tone, and the alarm tone is present. At the target range, the error tone will fade, but the simulated missile will continue its flight until all the thrusters have fired. The missile will then fall, simulating a ballistic trajectory. There will be no audible or visible hit indication. At computed ground impact, the TTY will print "SHOT NO. XX+2 MISSED ON (DATE) AT (TIME)," "LEFT OR RIGHT (XX) M," and "UP OR DOWN (XX) M."

30. Repeat steps 21 and 22.

31. Repeat steps 24 to 30, except that the gunner should shift the aiming point down into the ground. At the computed ground impact, the TTY will print "SHOT NO. XX+3 MISSED ON (DATE) AT (TIME)" and "HIT GROUND."

The system is now ready for use.

A-3.3 Typical Use

For a training effectiveness test, the operator should perform the following after completing the preoperational checks (sect. A-3.2.2):

1. Position the target vehicle at the desired range.

2. Enter the required data through "TARGET ELEVATION (M)" until the TTY pauses for completion of the shot (see sect. A-3.2.2, step 13).

3. The test crew and the gunner trainee take their required positions.

4. Check that the gunner is ready.

5. When the target is to be moving, alert the target vehicle operator.

6. Start the target motion (if the target is used).

7. Turn on the radio and the video tape recorder switch.

8. Use the microphone to enter the shot number.

9. Advise the gunner to fire when he is ready.

10. The gunner pulls the trigger in a simulated Dragon engagement.

11. After the end of the flight, turn off the video tape recorder switch and the radio.

12. When a moving target is used, advise the target vehicle operator to reposition the target as required.

13. Debrief the gunner as required.

14. For subsequent firings, repeat steps 1 to 13.

A-3.4 <u>Shutdown</u>

When the system is to be powered down, operate the main power breaker to the off position.

When a generator power supply is used, shut the engine down.

A-3.5 <u>Teardown and Stowage</u>

After the system is shut down, the parts may be disconnected and stowed.

1. Disconnect the external power cable.

2. Remove the tracker simulator from the launch tube and place the simulator in the box provided. Coil the cable to the tracker simulator into the box, and store the box in the van.

3. Fold the launch tube bipod. Fold the launch tube rest tripod. Store these two items in the van. Note: Before closing the van doors, ensure that (1) all equipment is properly stored and not likely to shift while the van is in motion and (2) no cables are in a position to be pinched by the doors.

4. Close and lock the rear double doors.

5. If the van is to be left unattended, lock both front doors.

A-4. MAINTENANCE

During the initial field trials of the simulator, all system maintenance will be performed by HDL personnel who will have worked with the system during fabrication, assembly, and checkout. Due to the developmental nature of the system and the fact that this system is a prototype, no attempt will be made to furnish maintenance instructions. Where maintenance information already exists, as for purchased hardware, the applicable manuals are referred to.

A-4.1 Diagnostic Routines

All diagnostic checking will be done by HDL personnel.

A-4.2 Tracker Boresighting

The tracker will be boresighted only by HDL personnel.

A-4.3 Optical and Electronics

A-4.3.1 Optical

Optical maintenance of the simulator cannot be accomplished in the field. Refer servicing to a qualified optical repair facility.

A-4.3.2 Electronics

Maintenance instructions for the tracker cathode ray tube electronics are given in the Sony KV-5000 Service Manual;[1] for the color videcon camera, in the Sony DXC-1600 Service Manual;[2] and for the silicon target black and white videcon, in the RCA TC 1005 Service Manual.[3]

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[1] *SONY Service Manual, KV-5000 Trinitron Color TV, SONY Corp., New York (1973); Supplements (November 1973, June 1974).*

[2] *SONY Service Manual, DXC-1600 Color Camera, Vol. 1, 2, SONY Corp., New York [n.d.]; Supplement (April 1975).*

[3] *Closed-Circuit Video Equipment, Camera Model TC1005, Operating Instructions, RCA, Closed-Circuit Video Equipment, Lancaster, PA [n.d.].*

A-4.4 Computer

Computer maintenance instructions are in the NOVA 1200 manuals from Data General Corp.[4]

A-4.5 Television Monitor

Television monitor equipment should be maintained by a qualified TV repair facility. Adjustments are described in the equipment operating manual.[5]

A-4.6 Video Tape Recorder

Video tape recorder equipment should be maintained by a qualified Sony repair facility. Operating procedures are described in the Sony AV-3600 manual.[6]

A-4.7 Teletype

The TTY equipment should be repaired by a qualified TTY maintenance facility.

A-4.8 Low Voltage Supplies

Maintenance instructions for low voltage supplies are in the Powermate OEM-18-D and PXS-D-5V and Dynage KH-12-12 maintenance manuals.[7-9]

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[4] *Technical Manual NOVA 1200, Data General Corp. 015-000002, Rev. 3, Southboro, MA (July 1973).*

[5] *CONRAC Television Monitor Model SNA, Installation and Operating Instructions, CONRAC Corp., Covina, CA [n.d.].*

[6] *SONY Service Manual, AV-3600 Videocorder, SONY Corp., New York (1970); Supplements (August 1971, February 1973).*

[7] *Operating Instructions for Regulated Power Supply, Model OEM-18-D, Power/Mate Corp., Hackensack, NJ [n.d.].*

[8] *Operating Instructions for Regulated Power Supply, Model PSX-D-5V, Power/Mate Corp., Hackensack, NJ [n.d.].*

[9] *Operating Instructions for Model KH-12-2 Power Supply, Dynage, Inc., Bloomfield, CN [n.d.].*

APPENDIX B.--COMPLETE PROGRAM LISTING OF THE DRAGON SIMULATOR IN NOVA ASSEMBLY LANGUAGE

The Dragon simulator program in NOVA assembly language is listed in this appendix.

APPENDIX B

```
      000013          .DUSR   REV      = 11.            ; 28 JUNE 76
      000074          .DUSR   DRATE    = 60.            ; DATA RATE IS 60 HZ

      000000                  .LOC 0
00000 000000                  0                   ; INTERRUPTED PC STORED HERE
00001 003250                  IMON                ; INTERRUPT POINTER
00002 002246 PRST:            JMP @ PWRUL         ; POWER RESTART ADDRESS
00003 002247 DRST:            JMP @ DGNSL         ; DRAGON TRAINER RESTART ADDRESS
00004 002250                  JMP @ BTSTL         ; BEACON TEST PROGRAM
00005 002251                  JMP @ MTSTL         ; MISSILE IMAGE TEST PROGRAM
00006 002252                  JMP @ ALGNL         ; CAMERA ALIGNMENT TEST PROGRAM
00007 002240                  JMP @ STSTL         ; SOUND TESTS

      000024          .LOC 24           ; AUTO INDEX LOCATIONS
00024 000000 INDTP:   0                           ; USED BY I/O ROUTINES
00025 000000 DFMIP:   0                           ; USED BY FLAME DELAY BUFFER LOADER

      000040          .LOC 40
                      ; CONSTANTS

00040 000002 P2:      2
00041 000004 P4:      4
00042 000005 P5:      5
00043 000006 P6:      6
00044 000007 P7:      7
00045 000011 P9.:     9.
00046 000012 P10.:    10.
00047 000013 P11.:    11.
00050 000014 P12.:    12.
00051 000015 P13.:    13.
00052 000017 P15.:    15.
00053 000026 P22.:    22.
00054 000027 P23.:    23.
00055 000030 P24.:    24.
00056 000036 P30.:    30.
```

```
00057 000037  P31.:    31.
00060 000055  P45.:    45.
00061 000073  P59.:    59.
00062 000074  P60.:    60.
00063 000100  P100:    100
00064 000103  P67.:    67.
00065 000114  P76.:    76.
00066 000143  P99.:    99.
00067 000177  P177:    177
00070 000200  P200:    200
00071 000237  P159.:   159.
00072 000377  P377:    377
00073 000764  P500.:   500.
00074 001335  P733.:   733.
00075 177400  UPMSK:   177400
00076 000074  SECND:   DRATE
00077 040000  UNCLR:   40000          : FAKE IOCLR
00100 140000  UNPLS:   140000         : FAKE IOPLS
00101 177375  IMASK:   177375         : INTERRUPT ENABLE MASK FOR TTY & DIO
00102 004000  BIT4:    4000
00103 002000  BIT5:    2000
00104 001000  BIT6:    1000
00105 000400  BIT7:    400
00106 000077  MSK6:    77
00107 007777  MSK12:   7777

                       : ASCII CHARACTERS

00110 000015  ASCCR:   15
00111 000055  ASCDS:   "-
00112 000116  ASCN:    "N
00113 000131  ASCY:    "Y
00114 000057  ASCSL:   "/
00115 000072  ASCCN:   ":
00116 000060  ASCO:    "O
00117 000040  ASCSP:   40
```

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```
                                : GENERAL STORAGE

00120 000000  BCNDY:   0   ; BEACON HORIZONTAL DISPLACEMENT FROM AIM POIN (SCAN LINES)
00121 000000  BCNDZ:   0   ; BEACON VERTICAL DISPLACEMENT FROM AIM POINT (SCAN LINES)
00122 000000  MONTH:   0   ; TODAY'S DATE SORAGE
00123 000000  DAY:     0
00124 000000  YEAR:    0
00125 000000  HOURS:   0   : TIME OF DAY
00126 000000  MINS:    0
00127 000000  SECS:    0
00130 000000  TGRNG:   0   : TARGET RANGE IN METERS
00131 000000  TGSPD:   0   : TARGET CROSSING SPEED IN KILOMETERS/HOUR
00132 000000  TGEL:    0   : TARGET ELEVATION IN METERS
00133 000000  SKYCN:   0   ; SKY CONDITION, NON ZERO => CLEAR SKY
00134 000000  AUDIO:   0   ; -1 => AUDIO AIMING AIDES ENABLED
00135 000000  VIDEO:   0   ; -1 => MISSILE IMAGE ENABLED
00136 000000  HITAV:   0   ; HIT/MISS INDICATION REQUESTED FOR TRACKER
00137 000000  HITFG:   0   ; HIT FLAG, (5/4)*(FRAME # OF HIT)
00140 000000  EXPFG:   0   ; IMPACT FLAG FOR I/O, NON-ZERO => GENERATE A VIDEO EXPLOSION
00141 000000  MISFG:   0   ; MISS FLAG, NON-ZERO ON A MISS OR ABNORMAL TERMINATION
00142 000000  SHTNO:   0   ; SHOT SERIAL NUMBER
00143 000000  FRFLG:   0   ; FLAME ON FLAG,NONZERO => THRUSTER FIRE NEXT INTERVAL
00144 000000  TRGEN:   0   ; TRIGGER ENABLE FLAG, -1 => TRIGGER ENABLED
00145 000000  TOF:     0   : TIME OF FLIGHT COUNTER IN 30THS OF A SECOND
00146 000000  STEP:    0   ; FRAME NUMBER SINCE FIRST MOTION
00147 000000  IMODO:   0   ; INPUT MODE WORD 0
00150 000000  OMODO:   0   : OUTPUT MODE, THRUSTER WORD
00151 000000  OMOD1:   0   : OUTPUT MODE, ERROR TONE WORD
00152 000000  EZ:      0   : BEACON, CURRENT VERTICAL POSITION
00153 000000  EY:      0   : BEACON, CURRENT HORIZONTAL POSITION
00154 000000  X:       0   ; X IN M
00155 000000  Y:       0   ; Y IN CM
00156 000000  Z:       0   ; Z IN CM
00157 000000  VY:      0
00160 000000  VZ:      0
```

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```
00161 000000   XOUT:    0          ; X MISSILE POSITION IN METERS
00162 000000   YOUT:    0          ; Y MISSILE POSITION IN SCAN LINES
00163 000000   ZOUT:    0          ; Z MISSILE POSITION IN SCAN LINES
00164 000000   TCNT1:   0          ; TEMPORARY COUNTER
00165 000000   TCNT2:   0          ; TEMPORARY COUNTER
00166 000000   DFMIC:   0          ; FLAME DELAY INPUT COUNT
00167 000000   DFMOP:   0          ; DELAYED FLAME OUTPUT POINTER
00170 000000   DFMOC:   0          ; DELAYED FLAME OUTPUT COUNT
00171 004247   DFMBP:   DFLMB-1    ; DELAYED FLAME BUFFER SA-1
00172 000000   ENMOD:   0          ; FLIGHT END MODE, 0=> LOST
                                   ; NON ZERO => NORMAL FLIGHT TERMINATION
00173 000000   SYSMD:   0          ; SYSTEM MODE
                                   ; 0 => PWRUP, 1 => DGNST, 2 => RUN, 3 => DGNEN
00174 001007   NWPRL:   NWPAR

                        ; DEVICE BUFFERS AND CONTROL BLOCKS

      000003   KBBLK:   .BLK 3     ; KEYBOARD DEVICE CONTROL BLOCK
                                   ; WORD 0, NONZERO WHEN A CHARACTER DESIRED IN KBBLK+2
                                   ; WORD 1, NONZERO WHEN A CHARACTER IS IN KBBLK+2
                                   ; WORD 2, LAST CHARACTER RECEIVED STORAGE

00200 000200   MSFMB:   .
      000010   MSBUF:   .BLK 8.    ; MISSILE DATA BUFFER
      000005   MSFLB:   .BLK 5     ; FLAME DATA BUFFER

                        ; SUBROUTINE LINKS

00216 002757   TODL:    TOD        ; TIME OF DAY COUNTER
00217 002603   KBCIL:   KBCI       ; KEYBOARD GET A CHARACTER, INTERRUPT
00220 002540   KBBIL:   KBBI       ; KEYBOARD GET A BUFFER, INTERRUPT
00221 002627   TTCNL:   TTCNI      ; TELETYPE PUT A CHARACTER, NO INTERRUPT
00222 002637   PRTBL:   PRTBF      ; PRINT A BUFFER
00223 002641   PRTLL:   PRTLN      ; PRINT A LINE WHOSE ADDRESS IS PASSED THRU AC2
00224 002443   ASCBL:   ASCBN      ; ASCII TO BINARY INPUT ROUTINE
00225 002722   BA.2L:   BNA.2      ; 2 DIGIT UNSIGNED BINARY TO ASCII
```

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```
00226 002401  BA.5L:  BNA.5    ; 5 DIGIT UNSIGNED BINARY TO ASCII
00227 002737  B3.1L:  BN3.1    ; PRINT AN UNSIGNED BINARY NUMBER IN F3.1 FORMAT
00230 002367  SEQLL:  SEQLC    ; SIGNED INEQUALITY CHECKER
00231 002374  EQLCL:  EQLC     ; UNSIGNED INEQUALITY CHECKER
00232 002657  YORNL:  YORN     ; GET A YES OR NO FROM THE KEYBOARD
00233 001755  SBM1L:  SUBM1    ; COMPUTES SQUARES IN 12 BITS FOR MISSILE OUTPUT
00234 003000  SBM7L:  SUBM7    ; COMPUTES THE AIMING ERROR WORD
00235 005105  BECNL:  BECON    ; READS THE I.R. BEACON
00236 005150  MSFML:  MISFM    ; OUTPUTS THE MISSILE/FLAME
00237 005143  HZ60L:  HZ60     ; WAITS FOR A 60 HZ FLAG FROM THE DIO
00240 005331  STSTL:  STEST    ; SOUND TESTS

                      : GENERAL POINTERS FOR MAIN SIMULATOR LOOP

00241 002067  ALIST:  LOST
00242 000146          STEP
00243 001755          SUBM1
00244 002064          SCORE
00245 001044          START

                               : GENERAL LINKS

00246 000415  PWRUL:  PWRUP    ; POWER UP
00247 000564  DGNSL:  DGNST    ; DRAGON START
00250 005040  BTSTL:  BTEST    ; I.R. BEACON TEST PROGRAM, RETURNS TO DEBUG III
00251 005000  MTSTL:  MTEST    ; MISSILE SPOT TEST PROGRAM, RETURNS TO DEBUG III
00252 005176  ALGNL:  ALIGN    ; TRACKER ALIGNMENT PROGRAM
00253 000402  DIAGL:  DIAG     ; DIAGNOSTIC CONTROLLER, ENTERED ON CTRL/P
00254 010000  DEBUG:  10000    ; S.A. OF DEBUG III (CHANGE TO PWRUP AFTER CHECKOUT)
```

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```
      000400                   .LOC 400

00400 003172  PFALL:  PFAIL
00401 002777  TDDRL:  TDDRC

                               ; DIAGNOSTIC CONTROLLER, ENTERED ON CTRL/P

00402 060277  DIAG:            INTDS
00403 102000                   ADC 0, 0
00404 062177                   ENMSK 0          ; ENABLE POWER FAIL INTERRUPTS
00405 060477                   READS 0
00406 030044                   LDA 2, P7
00407 024041                   LDA 1, P4
00410 143400                   AND 2, 0         ; MASK OUT UPPER BITS
00411 006231                   JSR @ EQLCL      ; ALLOW S.A.'S OF 4 5 6 7
00412 000415                   PWRUP            ; ILLEAGAL SWITCH SETTING
00413 111000                   MOV 0, 2
00414 001000                   JMP 0, 2         ; START THE REQUESTED DIAGNOSTIC

                               ; POWER UP SEQUENCE

00415 060210  PWRUP:           NIOC TTI         ; CLEAR THE KEYBOARD
00416 062400                   CLR 0
00417 040175                   STA 0, KBBLK     ; CLEAR THE CHARACTER REQUEST FLAG
00420 040176                   STA 0, KBBLK+1   ; CLEAR THE CHARACTER RECEIVED FLAG
00421 040173                   STA 0, SYSMD     ; SET SYSTEM TO POWER UP MODE
00422 040144                   STA 0, TRGEN     ; DISABLE THE TRIGGER
00423 040137                   STA 0, HITFG     ; CLEAR THE HIT FLAG
00424 040141                   STA 0, MISFG     ; CLEAR THE MISSED FLAG
00425 040150                   STA 0, OMODO     ; CLEAR THE OUTPUT MODE WORDS
00426 040151                   STA 0, OMOD1
00427 020076                   LDA 0, SECND
00430 042751                   STA 0, @ TDDRL   ; BE SURE TDDRC ISN'T SET TO 0
00431 102000                   ADC 0, 0
00432 040145                   STA 0, TOF       ; SET THE TIME OF FLIGHT
```

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```
00433 020077          LDA 0, UNCLR
00434 061142          DOAS 0, DIO      ; CLEAR THE DIO CONTROLLER
00435 020101          LDA 0, IMASK
00436 063777          SKPDZ CPU        ; CHECK POWER FAIL BEFORE ENABLING INTERRUPTS
00437 002741          JMP @ PFALL      ; POWER DIED
00440 062177          ENMSK 0          ; ENABLE TTI, DIO & POWER FAIL INTERRUPTS
00441 020040          LDA 0, P2        ; DO A 5 SEC DELAY FOR TTY TO GET UP TO SPEED
00442 040165          STA 0, TCNT2
00443 062400          CLR 0
00444 040164          STA 0, TCNT1
00445 014164          DSZ TCNT1
00446 000777          JMP .-1
00447 014165          DSZ TCNT2
00450 000775          JMP .-3
00451 020110          LDA 0, ASCCR     ; CR & LF
00452 006221          JSR @ TTCNL
00453 006221          JSR @ TTCNL
00454 006222          JSR @ PRTBL
00455 004022          TXTU             ; DO A LITTLE ADVERTISING
```

APPENDIX B

```
                        ; GET TODAY'S DATE MM/DD/YY
00456 020110  DATGT:          LDA 0, ASCCR      ; START WITH CR & LF
00457 006221                  JSR @ TTCNL
00460 006222                  JSR @ PRTBL
00461 003576                  TXTA              ; /DATE (MM/DD/YY)? /
00462 006224                  JSR @ ASCBL       ; GET THE MONTH IN AC1
00463 001057                  2*UH+"/
00464 000456                  DATGT             ; BAD CHARACTER RETURN
00465 121000                  MOV 1, 0
00466 126520                  CIA 1, 1
00467 030050                  LDA 2, P12.
00470 006231                  JSR @ EQLCL       ; CHECK VALIDITY
00471 000456                  DATGT             ; NO GOOD
00472 040122                  STA 0, MONTH
00473 006224                  JSR @ ASCBL       ; GET DAY
00474 001057                  2*UH+"/
00475 000456                  DATGT
00476 121000                  MOV 1, 0
00477 126520                  CIA 1, 1
00500 030057                  LDA 2, P31.
00501 006231                  JSR @ EQLCL
00502 000456                  DATGT
00503 040123                  STA 0, DAY
00504 006224                  JSR @ ASCBL       ; GET YEAR
00505 001015                  2*UH+15           ; CR
00506 000456                  DATGT
00507 121000                  MOV 1, 0
00510 024065                  LDA 1, P76.
00511 030066                  LDA 2, P99.
00512 006231                  JSR @ EQLCL
00513 000456                  DATGT
00514 040124                  STA 0, YEAR
```

APPENDIX B

```
                          ; GET TIME OF DAY          HH:MM:SS
00515 000403  TODGT:        JMP TODG1           ; FOLLOWING CRLF USED ON ERRORS ONLY
00516 020110  TODGO:        LDA 0, ASCCR
00517 006221                JSR @ TTCNL         ; DO CRLF ON ERROR
00520 006222  TODG1:        JSR @ PRTBL
00521 003610                TXTB                ; /TIME (HH:MM:SS)? /
00522 006224                JSR @ ASCBL         ; GET HOURS
00523 001072                2*UH+":
00524 000516                TODGO
00525 121000                MOV 1, 0
00526 066400                CLR 1
00527 030054                LDA 2, P23.
00530 006231                JSR @ EQLCL
00531 000516                TODGO
00532 030055                LDA 2, P24.
00533 112400                SUB 0, 2            ; AC2 <= 24. - HOURS
00534 050125                STA 2, HOURS
00535 006224                JSR @ ASCBL         ; GET MINUTES
00536 001072                2*UH+":
00537 000516                TODGO
00540 121000                MOV 1, 0
00541 066400                CLR 1
00542 030061                LDA 2, P59.
00543 006231                JSR @ EQLCL
00544 000516                TODGO
00545 030062                LDA 2, P60.
00546 112400                SUB 0, 2            ; AC2 = 60. - MINUTES
00547 050126                STA 2, MINS
00550 006224                JSR @ ASCBL         ; GET SECONDS
00551 001015                2*UH+15             ; CR
00552 000516                TODGO
00553 121000                MOV 1, 0
00554 066400                CLR 1
00555 030061                LDA 2, P59.
00556 006231                JSR @ EQLCL
```

```
00557 000516          TODGO
00560 030062          LDA 2, P60.
00561 112400          SUB 0, 2          ; AC2 = 60. - SECONDS
00562 050127          STA 2, SECS
00563 000401          JMP DGNST
```

APPENDIX B

```
                                   : INITIALIZATION OF THE MAIN SIMULATOR LOOP

00564 126520  DGNST:              CIA 1, 1
00565 044173                      STA 1, SYSMD : SET THE SYSTEM TO START MODE
00566 062400                      CLR 0
00567 040144                      STA 0, TRGEN : CLR THE TRIGGER ENABLE FLAG
00570 040137                      STA 0, HITFG : CLEAR THE HIT FRAME COUNT
00571 040141                      STA 0, MISFG : CLEAR THE MISSED FLAG
00572 040150                      STA 0, OMODO : CLEAR THE OUTPUT MODE WORDS
00573 040151                      STA 0, OMOD1
00574 102000                      ADC 0, 0
00575 040145                      STA 0, TOF   : RESET THE TIME OF FLIGHT TO BE 0 1ST TIME THRU
00576 020056                      LDA 0, P30.
00577 040166                      STA 0, DFMIC : RESET THE THRUSTER INPUT COUNT
00600 040170                      STA 0, DFMOC ; RESET THE THRUSTER OUTPUT COUNT
00601 020171                      LDA 0, DFMBP : SET UP THE THRUSTER BUFFER POINTERS
00602 040025                      STA 0, DFMIP
00603 101400                      INC 0, 0
00604 040167                      STA 0, DFMOP
00605 062400  GO:        CLR 0
00606 040154             STA      0,X
00607 040155             STA      0,Y
00610 040156             STA      0,Z
00611 040157             STA      0,VY
00612 000411             JMP      GO1
      000012             .RDX 10
00613 000143  IVZ:       99
00614 001507  ADR1:      ZS1
00615 001510             ZS2
00616 001511             ZTOTAL
00617 001504             YS1
00620 001505             YS2
00621 001513             J
00622 000163             115
00623 042771  GO1:       STA      0,@ADR1 :SET ZS1=0
00624 042771             STA      0,@ADR1+1       :ZS2=0
```

```
00625 042772        STA    0,@ADR1+3         :YS1=0
00626 042772        STA    0,@ADR1+4         :YS2=0
00627 040146        STA    0,STEP  :STEP=0
00630 020772        LDA    0,ADR1+6          :LOAD 115
00631 042765        STA    0,@ADR1+2         :SET ZTOTAL=115
00632 020761        LDA    0,IVZ             :IVZ IS 99
00633 040160        STA    0,VZ              :SET STARTING VZ

      000010        .RDX 8
```

APPENDIX B

```
                          ; GET THE SHIT PARAMETERS

00634 020110  INITO:        LDA 0, ASCCR
00635 006221                JSR @ TTCNL      ; CRLF
00636 006222                JSR @ PRTBL
00637 003771                TXTD             ; /NEW PARAMETERS /
00640 006232                JSR @ YORNL      ; EVOKE YES OR NO
00641 102001                ADC 0, 0, SKP    ; YES
00642 062400                CLR 0            ; NO
00643 040544                STA 0, NWPAR
00644 020110                LDA 0, ASCCR
00645 006221                JSR @ TTCNL      ; DO A CRLF
00646 020064                LDA 0, P67.
00647 040164                STA 0, TCNT1     ; SET UP 67. COLUMN COUNTER
00650 020111                LDA 0, ASCDS     ; ASCII '-'
00651 006221                JSR   TTCNL      ; PRINT A DASH
00652 014164                DSZ TCNT1        ; SKIP IF DONE 72.
00653 000776                JMP .-2
00654 020110                LDA 0, ASCCR
00655 006221                JSR @ TTCNL      ; DO A CR & LF
00656 006221                JSR @ TTCNL      ; & ANOTHER LF
00657 022174                LDA 0, @ NWPRL
00660 101005                MOV 0, 0, SNR    ; SKIP IF NEW PARAMETERS REQUIRED
00661 000451                JMP RNGGT

                    ; GET INSTRUCTOR ID - ANY STRING (10 CHARS OR LESS) ENDING WITH CR

00662 006222  TCHGT:        JSR @ PRTBL
00663 003731                TXTK             ; /INSTRUCTOR ID? /
00664 020523                LDA 0, NWPAR
00665 101005                MOV 0, 0, SNR    ; SKIP IF GETTING NEW PARAMTERS
00666 000405                JMP TCHGO
00667 006220                JSR @ KBBIL      ; GET A BUFFER
00670 000012                10.              ; 10. CHARS LONG
00671 010470                TCHID*2          ; AND STORE IN TCHID
00672 000403                JMP TCHG1        ; GO ON TO THE NEXT ITEM
```

APPENDIX B

```
00673 006222  TCHGO:          JSR @ PRTBL
00674 004234                  TCHID             ; TYPE THE INSTRUCTOR ID
      000000  TCHG1:

                      ; GET GUNNER ID - ANY STRING (10 CHARS OR LESS) ENDING WITH A CR

00675 006222  GNRGT:          JSR @ PRTBL
00676 003622                  TXTC              ; /GUNNER ID? /
00677 020510                  LDA 0, NWPAR
00700 101005                  MOV 0, 0, SNR     ; SKIP IF GETTING NEW PARAMETERS
00701 000405                  JMP GNRG0
00702 006220                  JSR @ KBBIL
00703 000012                  10.
00704 010504                  GNRID*2
00705 000403                  JMP GNRG1         ; GO ON TO THE NEXT ITEM
00706 006222  GNRG0:          JSR @ PRTBL
00707 004242                  GNRID             ; TYPE THE GUNNER ID
      000000  GNRG1:
```

```
                        ; GET THE SKY CONDITION (CLEAR OR NOT)

00710 020133                    LDA 0, SKYCN      ; GET THE OLD SKY CONDITION
00711 004501                    JSR PARGT         ; TYPE IT OR GET A NEW ONE
00712 003742                    TXTL              ; /SKY CONDITION
00713 040133                    STA 0, SKYCN      ; STORE THE NEW OR OLD

                        ; AUDIO AIMING AIDS ?????

00714 020134                    LDA 0, AUDIO      ; FETCH THE OLD PARAMETER
00715 004475                    JSR PARGT
00716 003677                    TXTG
00717 040134                    STA 0, AUDIO

                        ; MISSILE IMAGE ON ?????

00720 020135                    LDA 0, VIDEO
00721 004471                    JSR PARGT
00722 003711                    TXTH
00723 040135                    STA 0, VIDEO

                        ; HIT/MISS INDICATION FOR DISPLAY ?????

00724 020136                    LDA 0, HITAV
00725 004465                    JSR PARGT
00726 003750                    TXTM
00727 040136                    STA 0, HITAV
00730 020110                    LDA 0, ASCCR
00731 006221                    JSR @ TTCNL       ; CRLF

                        ; GET TARGET RANGE IN METERS - MAXIMUM OF 4 DIGITS

00732 000403  RNGGT:            JMP RNGG1
00733 020110  RNGG0:            LDA 0, ASCCR
00734 006221                    JSR @ TTCNL       ; DO CRLF ON ERROR ONLY
00735 006222  RNGG1:            JSR @ PRTBL
```

```
00736 003631            TXTD               ; /TARGET RANGE (M)? /
00737 006224            JSR @ ASCBL        ; GET TARGET RANGE
00740 002015            4*UH+15            ; CR
00741 000733            RNGGO              ; BAD CHARACTER
00742 125112            MOVL# 1, 1, SZC
00743 000770            JMP RNGGO          ; DON'T ALLOW NEGATIVE RANGES
00744 044130            STA 1, TGRNG
```

APPENDIX B

```
                                  ; GET TARGET CROSSING SPEED IN KPH - MAXIMUM OF 3 DIGITS

00745 000403  SPDGT:            JMP SPDG1
00746 020110  SPDG0:            LDA 0, ASCCR
00747 006221                    JSR @ TTCNL       ; DO CRLF ON ERROR ONLY
00750 006222  SPDG1:            JSR @ PRTBL
00751 003643                    TXTE              ; /TARGET CROSSING SPEED (KPH)? /
00752 006224                    JSR @ ASCBL       ; GET TARGET CROSSING SPEED
00753 001415                    3*UH+15           ; CR
00754 000746                    SPDG0             ; BAD CHARACTER
00755 044131                    STA 1, TGSPD
00756 062400                    CLR 0             ; MULT TARGET SPEED BY 9.
00757 135000                    MOV 1, 3
00760 030045                    LDA 2, P9.
00761 175112                    MOVL# 3, 3, SZC ; TAKE ABS VALUE OF TGSPD
00762 124400                    NEG 1, 1
00763 073301                    MUL
00764 175112                    MOVL# 3, 3, SZC ; SET THE SIGN OF SPD*9.
00765 124400                    NEG 1, 1          ; SINGLE PRECISION RESULT
00766 046455                    STA 1, @ YRL      ; STORE IN YR
```

```
                     ; GET TARGET ELEVATION IN METERS - MAXIMUM OF 3 DIGITS

00767 066400  ELGT:          CLR 1             ; ***** TEMP *****
00770 000411                 JMP ELG2          ; ***** TEMP *****
00771 000403                 JMP ELG1
00772 020110  ELG0:          LDA 0, ASCCR
00773 006221                 JSR @ TTCNL       ; DO CRLF ON ERROR ONLY
00774 006222  ELG1:          JSR @ PRTBL
00775 003663                 TXTF              ; /TARGET ELEVATION (M)? /
00776 006224                 JSR @ ASCBL
00777 001415                 3*UH+15           ; CR
01000 000772                 ELG0              ; BAD CHARACTER
01001 044132  ELG2:          STA 1, TGEL

                     ; BE SURE THAT THE MISSILE STAYS OFF UNTIL THE TRIGGER IS PULLED
                     ; ENABLE THE TRIGGER AND WAIT.

01002 020102                 LDA 0, BIT4
01003 040207                 STA 0, MSBUF+6    ; SET THE MISSILE OFF BIT
01004 040215                 STA 0, MSFLB+4    ; SET THE FLAME OFF BIT
01005 040144                 STA 0, TRGEN      ; ENABLE THE TRIGGER
01006 000437                 JMP STRT2         ; GO WAIT FOR THE TRIGGER

                     ; MISC STORAGE

01007 000000  NWPAR:  0                        ; NON ZERO => NEW PARAMTERS REQUESTED
01010 004001  TXTPL:  TXTP
01011 004005  TXTQL:  TXTQ

                     ; ROUTINE USED TO GET PARAMETERS WITH YES OR NO RESPONSES

01012 040424  PARGT:         STA 0, PARTM      ; SAVE THE OLD VALUE
01013 031400                 LDA 2, 0, 3       ; GET THE TITLE ADDRESS
01014 175400                 INC 3, 3
01015 054420                 STA 3, PARRT      ; SAVE THE RETURN
01016 006223                 JSR @ PRTLL       ; TYPE THE TITLE IN AC2
```

```
01017 020770              LDA 0, NWPAR
01020 101005              MOV 0, 0, SNF   ; SKIP IF GETTING NEW PARAMETER
01021 000405              JMP PARGO
01022 006232              JSR @ YORNL     ; GET THE YES OR NO RESPONSE
01023 102001              ADC 0, 0, SKP   ; 'YES'
01024 062400              CLR 0           ; 'NO'
01025 002410              JMP @ PARRT     ; RETURN
01026 020410   PARGO:     LDA 0, PARTM    ; FETCH THE OLD PARAMETER
01027 030761              LDA 2, TXTPL
01030 101005              MOV 0, 0, SNR   ; SKIP IF IT IS 'YES'
01031 030760              LDA 2, TXTQL
01032 006223              JSR @ PRTLL     ; TYPE IT
01033 020403              LDA 0, PARTM    ; REFETCH THE PARAMETER VALUE
01034 002401              JMP @ PARRT     ; RETURN

01035 000000   PARRT:  0
01036 000000   PARTM:  0
01037 000000   SEY:    0
01040 000000   STEZ:   0
01041 000000   DEY:    0
01042 000000   DEZ:    0
01043 001212   YRL:    YR
```

APPENDIX B

```
                             ; MAIN SIMULATOR LOOP

01044 006234  START:                JSR @ SBM7L       ; COMPUTE THE AIMING ERROR WORD
01045 000400  STRT2:    HANG                          ; WAIT FOR THE NEXT SYSTEM INTERRUPT
01046 020771  STRT1:    LDA         0,SEY
01047 024153            LDA         1,EY
01050 044767            STA         1,SEY
01051 106400            SUB         0,1               ;EY-SEY
01052 044767            STA         1,DEY
01053 020765            LDA         0,STEZ
01054 024152            LDA         1,EZ
01055 044763            STA         1,STEZ
01056 106400            SUB         0,1               ;EZ-STEZ
01057 044763            STA         1,DEZ

                             ; CHECK FOR MOTION

01060 030145                        LDA 2, TOF
01061 024053  STRTO:                LDA 1, P22.
01062 146533                        SSGT 2, 1          ; SKIP IF TOF > 22.
01063 000761                        JMP START          ; NO MOTION YET, WAIT FOR NEXT INTERRUPT
01064 020102                        LDA 0, BIT4
01065 040215                        STA 0, MSFLB+4     ; BE SURE THE FLAME ONLY FIRES FOR ONE CYCLE
```

APPENDIX B

```
        000012             .RDX 10

01066 020154               LDA     0,X                 ;START SECTION MOTION
01067 024514               LDA     1,GRP1                       ;3 IN AC1
01070 107000               ADD     0,1                 ;X INCREMENTED BY 3 M IN AC1
01071 044161               STA     1,XOUT
01072 044154               STA     1,X
01073 020155               LDA     0,Y
01074 024157               LDA     1,VY
01075 107000               ADD     0,1                 ;Y CHANGED BY ADDING VY
01076 044155               STA     1,Y
01077 020156               LDA     0,Z
01100 024160               LDA     1,VZ
01101 123000               ADD     1,0                 ;Z CHANGED BY ADDING VZ
01102 030502               LDA     2,GRP1+1            ;5 IN AC2 IS .5*G*T**2
01103 142400               SUB     2,0                 ;SUB 5 FROM Z
01104 040156               STA     0,Z
01105 020500               LDA     0,GRP1+2            ;11 IN AC0 IS G*T
01106 106400               SUB     0,1                 ;SET VZ=VZ-11
01107 044160               STA     1,VZ
01110 024502               LDA     1,YR
01111 030154               LDA     2,X
01112 102400               SUB     0,0
01113 115000               MOV     0,3
01114 125113               MOVL#   1,1,SNC             ;SKIP IF YR NEG
01115 000403               JMP     MD2
01116 175400               INC     3,3                 ;SET AC3=1
01117 124400               NEG     1,1                 ;CHANGE SIGN OF YR IN AC1
01120 073301       MD2:    MUL                 ;YR*X
01121 030130               LDA     2,TGRNG
01122 073101               DIV                 ;YR*X/TGRNG
01123 175004               MOV     3,3,SZR
01124 124400               NEG     1,1                 ;CHANGE SIGN
01125 034155               LDA     3,Y
01126 136400               SUB     1,3                 ;Y IN AC3
01127 054155               STA     3,Y
```

APPENDIX B

```
01130 030146          LDA     2,STEP          :INCREMENT STEP
01131 151400          INC     2,2
01132 050146          STA     2,STEP
01133 024706          LDA     1,DEY
01134 102400          SUB     0,0
01135 115000          MOV     0,3
01136 125113          MOVL#   1,1,SNC         :SKIP   IF DEY NEG
01137 000403          JMP     MD3
01140 175400          INC     3,3             :AC3=1
01141 124400          NEG     1,1
01142 073301   MD3:   MUL                     :DEY*STEP
01143 030045          LDA     2,P9.
01144 073301          MUL                     :DEY*STEP*5 IN AC0,AC1
01145 030053          LDA     2,P22.
01146 073101          DIV                     :AC1/AC2 IN AC1
01147 175004          MOV     3,3,SZR
01150 124400          NEG     1,1
01151 030155   YNRM:  LDA     2,Y
01152 133000          ADD     1,2
01153 050155          STA     2,Y
```

```
01154 020435          LDA     0,GRP1+6              :8000
01155 142132          SSLT    2,0                   :SKIP Y LT 8000
01156 002241          JMP     @ALIST
01157 100400          NEG     0,0
01160 142533          SSGT    2,0                   :SKIP Y GT -8000
01161 002241          JMP     @ALIST
01162 102400          SUB     0,0
01163 024430          LDA     1,YR+1                :4 IN AC1
01164 115000          MOV     0,3
01165 151113          MOVL#   2,2,SNC
01166 000403          JMP     MD4
01167 175400          INC     3,3
01170 150400          NEG     2,2
01171 073301  MD4:    MUL                           :4*Y IN AC1
01172 030146          LDA     2,STEP   :STEP
01173 073101          DIV
01174 102400          SUB     0,0
01175 030407          LDA     2,GRP1+1                   :5 IN AC2
01176 073101          DIV                           :Y*4/5/STEP
01177 175004          MOV     3,3,SZR
01200 124400          NEG     1,1
01201 044162          STA     1,YOUT
01202 000412          JMP     ZEE
01203 000003  GRP1:   3
01204 000005          5
01205 000013          11
01206 000010          8
01207 000020          16
01210 004000          2048
01211 017500          8000
01212 000000  YR:     0
01213 000004          4
01214 024626  ZEE:    LDA     1,DEZ
01215 030146          LDA     2,STEP   :STEP
01216 102400          SUB     0,0
01217 115000          MOV     0,3
```

```
01220 125113              MOVL#   1,1,SNC
01221 000403              JMP     MD5
01222 175400              INC     3,3
01223 124400              NEG     1,1
01224 073301     MD5:     MUL                       ;DEZ*STEP
01225 030045              LDA     2,P9.
01226 073301              MUL                       ;DEZ*STEP*5 IN AC1
```

```
01227 030053          LDA     2,P22.
01230 073101          DIV
01231 175004          MOV     3,3,SZR
01232 124400          NEG     1,1
01233 030156  ZNRM:   LDA     2,Z
01234 132400          SUB     1,2
01235 050156          STA     2,Z
01236 020753          LDA     0,GRP1+6          :8000
01237 142132          SSLT    2,0               :SKIP LT 8000
01240 002241          JMP     @ALIST
01241 101220          MOVZR   0, 0
01242 100640          NEGOR   0,0
01243 142533          SSGT    2,0               :SKIP  Z GT -2000
01244 002241          JMP     @ALIST
01245 102400          SUB     0,0
01246 024745          LDA     1,YR+1            :4 IN AC1
01247 115000          MOV     0,3
01250 151113          MOVL#   2,2,SNC           :SKIP IF Z NEG
01251 000403          JMP     MD6
01252 175400          INC     3,3
01253 150400          NEG     2,2
01254 073301  MD6:    MUL                       :4*Z
01255 032242          LDA     2,@ALIST+1        :STEP
01256 073101          DIV
01257 102400          SUB     0,0
01260 030724          LDA     2,GRP1+1          :5 IN AC2
01261 073101          DIV              :4*Z/STEP/5
01262 175004          MOV     3,3,SZR
01263 124400          NEG     1,1
01264 044163          STA     1,ZOUT
```

APPENDIX B

```
01265 024070   MSLX:   LDA     1,P200         :128.
01266 030162           LDA     2,YOUT
01267 133000           ADD     1,2            :SET RELATIVE TO UPPER LEFT
01270 150400           NEG     2,2
01271 024107           LDA     1, MSK12
01272 147400           AND     2, 1           ; MASK TO 12 BITS
01273 044201           STA     1,MSBUF        ; -Y
01274 006243           JSR     @ALIST+2       ;SUBM1
01275 054203           STA     3,MSBUF+2      ;Y*Y IN H.O.
01276 044204           STA     1,MSBUF+3      ;Y*Y IN L.O.
01277 024070           LDA     1,P200         ;128.
01300 030163           LDA     2,ZOUT
01301 132400           SUB     1,2            :SET RELATIVE TO UPPER LEFT
01302 024107           LDA     1, MSK12
01303 147400           AND     2, 1           ; MASK TO 12 BITS
01304 044202           STA     1,MSBUF+1      ;-Z
01305 006243           JSR     @ALIST+2       ;SUBM1
01306 054205           STA     3,MSBUF+4      ;Z*Z IN H.O.
01307 044206           STA     1,MSBUF+5      ;Z*Z IN L.O.
01310 020135           LDA     0, VIDEO
01311 101004           MOV     0, 0, SZR      ; SKIP IF MISSILE IS NOT ENABLED
01312 000404           JMP     MSLR           ; IT IS, FINISH COMPUTING THE OUTPUT BUFFER
01313 020102           LDA     0, BIT4        ; IT IS NOT, SET THE MISSILE OFF BIT
01314 040207           STA     0, MSBUF+6
01315 000413           JMP     DONE
01316 062400   MSLR:   CLR     0
01317 024071           LDA     1,P159.        :159.
01320 030161           LDA     2,XOUT
01321 155220           MOVZR   2,3            ;X/2
01322 167000           ADD     3,1            :159+X/2
01323 073101           DIV                    :(159+X/2)/X
01324 131000           MOV     1, 2
01325 006243           JSR     @ALIST+2       ;SUBM1
01326 054207           STA     3,MSBUF+6      ;R*R IN H.O.
01327 044210           STA     1,MSBUF+7      ;R*R IN L.O.
01330 030154   DONE:   LDA     2,X
```

```
01331 024130          LDA      1,TGRNG
01332 132513          SUBL#    1,2,SNC         :SKIP IF X-TGRNG LT 0
01333 002244          JMP      @ALIST+3        :SCORE
```

APPENDIX B

```
01334 024550   FIL:   LDA     1,YS1
01335 030155          LDA     2,Y
01336 050546          STA     2,YS1
01337 132400          SUB     1,2          :DIFFERENCE OF 2 Y VALUES
01340 024545          LDA     1,YS2
01341 147000          ADD     2,1          ;YSUM IN AC1
01342 135000          MOV     1,3
01343 125112          MOVL#   1,1,SZC      ;SKIP IF POSITIVE
01344 000405          JMP     MD7          ;JUMP IF NEG
01345 125220          MOVZR   1,1
01346 125220          MOVZR   1,1
01347 125220          MOVZR   1,1
01350 000404          JMP     MD8
01351 125240   MD7:   MOVOR   1,1
01352 125240          MOVOR   1,1
01353 125240          MOVOR   1,1
01354 171000   MD8:   MOV     3,2
01355 136400          SUB     1,3          ;YSUM*7/8 IN AC3
01356 054527          STA     3,YS2
01357 020155          LDA     0,Y
01360 151120          MOVZL   2,2          ;MULT BY 2
01361 113000          ADD     0,2
01362 050524          STA     2,YP         ;END FILTER Y
01363 024145          LDA     1,TOF
01364 030512          LDA     2,GRP2
01365 132432          SGT      1, 2        ; SKIP IF TOF > 35
01366 002245          JMP     @ALIST+4     ;START
01367 006527          JSR     @ADSR        ;SERCH
01370 024145          LDA     1, TOF
01371 030506          LDA     2,GRP2+1     :LOAD 36
01372 132414          SEQ     1, 2         ; SKIP IF TOF = 36
01373 000404          JMP     ZFIL
01374 020156          LDA     0,Z
01375 040512          STA     0,ZS1        :Z STORES IN ZS1
01376 000457          JMP     MD11
01377 024510   ZFIL:  LDA     1,ZS1        ;ZS1 IN AC1
```

```
01400 030156           LDA     2,Z
01401 050506           STA     2,ZS1
01402 132400           SUB     1,2              :ZDF IN AC2=Z-ZS1
01403 024505           LDA     1,ZS2            :ZS2 IN AC1
01404 133000           ADD     1,2              :ZSUM IN AC2
01405 024047           LDA     1,P11.   :11 IN AC1
01406 102400           SUB     0,0
01407 115000           MOV     0,3
01410 151113           MOVL#   2,2,SNC
01411 000403           JMP     MD9
01412 175400           INC     3,3
01413 150400           NEG     2,2
01414 073301    MD9:   MUL                      :ZSUM*11
01415 175004           MOV     3,3,SZR
01416 124400           NEG     1,1
01417 151220           MOVZR   2, 2
01420 175004           MOV     3, 3, SZR
01421 150400           NEG     2, 2
01422 050466           STA     2,ZS2            :STORE ZSUM IN ZS2
01423 032460           LDA     2,@GRP2+5
```

APPENDIX B

```
01424 147000          ADD     2,1              ;Z+11*ZSUM IN 1
01425 030453          LDA     2,GRP2+2         ;10 IN AC2
01426 102400          SUB     0,0
01427 115000          MOV     0,3
01430 125113          MOVL#   1,1,SNC
01431 000403          JMP     MD10
01432 175400          INC     3,3
01433 124400          NEG     1,1
01434 073101   MD10:  DIV                      ;ZP/10, ZP=Z+ZSUM*11
01435 175004          MOV     3,3,SZR
01436 124400          NEG     1,1
01437 034442          LDA     3,GRP2+3         ;214 IN AC3
01440 136400          SUB     1,3
01441 030450          LDA     2,ZTOTAL               ;ZTOTAL IN AC2
01442 173000          ADD     3,2
01443 050446          STA     2,ZTOTAL
01444 020143          LDA     0,FRFLG
01445 101004          MOV     0,0,SZR
01446 000452          JMP     COMPR+1
01447 024442          LDA     1,ZTOTAL
01450 030447          LDA     2,COMPR
01451 132133          SSGE    1, 2             ; SKIP IF ZTOTAL >= COMPR
01452 002443          JMP     @BEGIN
01453 020427          LDA     0,GRP2+4               ;115
01454 040435          STA     0,ZTOTAL
01455 024166   MD11:  LDA     1, DFMIC         ; GET THE THRUSTER INPUT COUNT
01456 125005          MOV     1, 1, SNR        ; SKIP IF THRUSTERS LEFT
01457 000413          JMP     MD12
01460 044143          STA     1, FRFLG         ; SET THE FIRE FLAG FOR NEXT TIME
01461 020576          LDA     0,DELVZ
01462 040577          STA     0,AZ
01463 020573          LDA     0,DELVY
01464 040574          STA     0,AY
01465 024145          LDA     1,TOF
01466 030411          LDA     2,GRP2+1
01467 132414          SEQ     1,2              ;SKIP IF TOF=36
```

APPENDIX B

```
01470 002425            JMP     @BEGIN
01471 000706            JMP     ZFIL
01472 062400  MD12:     CLR     0             ; NO THRUSTERS LEFT
01473 040565            STA     0, AY         ; CLEAR THE Y & Z ACCELERATIONS
01474 040565            STA     0, AZ
01475 002420            JMP     @ BEGIN       ; GO TO START
01476 000043  GRP2:     35
01477 000044            36
01500 000012            10
01501 000326            214
01502 000163            115
01503 000156            Z
01504 000000  YS1:      0
01505 000000  YS2:      0
01506 000000  YP:       0
01507 000000  ZS1:      0
01510 000000  ZS2:      0
01511 000000  ZTOTAL:   0
01512 000000  INT:      0
```

APPENDIX B

```
01513 000000  J:       0
01514 000000  JX:      0
01515 001044  BEGIN:   START
01516 001674  ADSR:    SERCH
01517 000000  COMPR:   0
01520 030540           LDA    2,AY
01521 034157           LDA    3,VY
01522 157000           ADD    2,3
01523 054157           STA    3,VY                    ; VY <= VY + AY
01524 030535           LDA    2,AZ
01525 034160           LDA    3,VZ
01526 157000           ADD    2,3
01527 054160           STA    3,VZ                    ; VZ <= VZ + AZ
01530 020525           LDA    0,ADR3
01531 040143           STA    0,FRFLG
01532 020135           LDA    0,VIDEO
01533 101004           MOV    0,0,SZR
01534 000417           JMP    FLAM1
01535 024403           LDA    1,DUD
01536 044215           STA    1,MSFLB+4       :WEF
01537 002756           JMP    @BEGIN
01540 004000  DUD:     2048
01541 000400  KONS:    256
01542 043600           18304  ;WIDTH OF FLAME*143
01543 004615           2445         :LINES PER RADIAN
01544 000764           500
01545 001750           1000
01546 000154           X
01547 000013           11
01550 000002           2
01551 000006           6
01552 000217           143
01553 024505  FLAM1:   LDA    1,AY
01554 030765           LDA    2,KONS
01555 062400           CLR    0
01556 115000           MOV    0,3
```

```
01557 125113           MOVL#    1,1,SNC
01560 000403           JMP      MDX13
01561 175400           INC      3,3
01562 124400           NEG      1,1
01563 073301  MDX13:   MUL                     ;AY*256
01564 030475           LDA      2,AZ
01565 141220           MOVZR    2,0
01566 107000           ADD      0,1
01567 062400           CLR      0
01570 073101           DIV                     ;AY*256/AZ
01571 175005           MOV      3,3,SNR
01572 124400           NEG      1,1
01573 034107           LDA      3, MSK12
01574 167400           AND      3, 1              ; MASK TO 12 BITS
01575 044213           STA      1,MSFLB+2         ;DLTYF
01576 066400           CLR      1
01577 044212           STA      1,MSFLB+1         ;ZERO FOR Z START
01600 030461           LDA      2,AZ
01601 024741           LDA      1,KONS+1          ;128 MM WIDTH OF FLAME*143=18304
01602 062400           CLR      0
01603 073101           DIV                        ;18304/AZ
01604 030737           LDA      2,KONS+2          ;2445
01605 020737           LDA      0,KONS+3          ;500
01606 073301           MUL                        ;AC1*AC2+AC0 IN AC0,AC1
01607 030736           LDA      2,KONS+4          ;1000
01610 073101           DIV                        ;IN AC1
01611 032735           LDA      2,@KONS+5         ;X
01612 151220           MOVZR    2,2               ;X/2 IN AC2
01613 147000           ADD      2,1
01614 151120           MOVZL    2,2               ;X
01615 062400           CLR      0
01616 073101           DIV                        ;WIDTH IN AC1
01617 034731           LDA      3,KONS+7          ;2
01620 136032           SGE      1,3               ;SKIP IF WIDTH GE 2
01621 165000           MOV      3,1               ;SET WIDTH=2
01622 034107           LDA      3, MSK12
```

APPENDIX B

```
01623 167400          AND     3, 1          : MASK TO 12 BITS
01624 044215          STA     1,MSFLB+4     ;
01625 130620          NEGZR   1,2           :-WIDTH/2
01626 173400          AND     3, 2          : MASK TO 12 BITS
01627 050211          STA     2,MSFLB
01630 030721          LDA     2,KONS+8      ;6
01631 062400          CLR     0
01632 073301          MUL                   ;6*WIDTH IN AC1
01633 030426          LDA     2,AZ
01634 073301          MUL                   ;AZ*6*WIDTH IN AC1
01635 030715          LDA     2,KONS+9      ;143
01636 073101          DIV                   ;6*WIDTH*COS(PHI)
01637 167400          AND     3, 1          ; MASK TO 12 BITS
01640 044214          STA     1,MSFLB+3     ;ZEF
01641 020166          LDA     0,DFMIC
01642 101005          MOV     0,0,SNR       ;SKIP IF THRUSTER LEFT
01643 002652          JMP     @BEGIN
01644 014166          DSZ     DFMIC         ;USE A THRUSTER
01645 000401          NOP
01646 020145          LDA     0, TOF        ;GET FRAME COUNT FROM TRIGGER PULL
01647 105220          MOVZR   0,1
01650 125222          MOVZR   1,1, SZC      ;DIVIDE IT BY4
01651 125400          INC 1, 1              ; ROUND UP
01652 107000          ADD     0,1           ;ADD XOUT TO XOUT/4
01653 046025          STA     1,@DFMIP      ;STORE THROUGH AUTO INDEX
01654 002641          JMP     @BEGIN
01655 000000  ADR3:   0
01656 000000  DELVY:  0
01657 000000  DELVZ:  0
01660 000000  AY:     0
01661 000000  AZ:     0
01662 000000  RETN1:  0
01663 000024          20
01664 000032          26
01665 000065          53
01666 004366          2294
```

```
01667 000043      35
01670 000113      75
01671 000154      X
01672 001506      YP
01673 001754      SGY
```

APPENDIX B

```
01674 054766  SERCH:  STA    3,RETN1
01675 024771          LDA    1,RETN1+4        :2294
01676 044621          STA    1,COMPR
01677 024607          LDA    1, YP
01700 102520          CIA    0, 0             ; SET SGY TO 1
01701 125113          MOVL#  1,1,SNC          :SKIP IF YP NEG
01702 000403          JMP    DOWN
01703 100400          NEG    0,0              :SGY IN ACO IS -1
01704 124400          NEG    1,1              :-YP IN AC1
01705 040447  DOWN:   STA    0,SGY
01706 020756          LDA    0,RETN1+2        :26
01707 107000          ADD    0,1              :YP+26 IN AC1
01710 062400          CLR    0
01711 030754          LDA    2,RETN1+3        :53
01712 073101          DIV                     :(YP+26)/53 IN AC1
01713 020755          LDA    0,RETN1+6        :75
01714 122033          SLT    1, 0             : SKIP IF PHI .LT. 75.
01715 105000          MOV    0,1
01716 044434          STA    1,PHI
01717 125220          MOVZR  1,1              :PHI KNOWN TO BE GT 0
01720 125400          INC    1,1              :PHI/2+1=J
01721 030430          LDA    2,LDVZ
01722 133000          ADD    1,2              :J+LDVZ
01723 021000          LDA    0,0,2
01724 040733          STA    0,DELVZ
01725 030423          LDA    2,LDVY
01726 133000          ADD    1,2              :J+LDVY
01727 021000          LDA    0,0,2            :DELVY
01730 024424          LDA    1,SGY
01731 125113          MOVL#  1,1,SNC          :SKIP IF SGY NEG
01732 100400          NEG    0,C              :DELVY HAS SIGN OPOSITE THAT OF ANGLE
01733 040723          STA    0,DELVY
01734 024416          LDA    1,PHI
01735 030726          LDA    2,RETN1+1        :20
01736 146420          SUBZ    2,1             :PHI-20 IN AC1
01737 125112          MOVL#  1,1,SZC
```

```
01740 002722          JMP    @RETN1
01741 030726          LDA    2,RETN1+5
01742 062400          CLR    0
01743 073301          MUL                    ;35*(PHI-20)
01744 032407          LDA    2,@PHI+1            :
01745 132400          SUB    1,2
01746 052405          STA    2,@PHI+1        ;COMPR
01747 002713          JMP    @RETN1
01750 004306  LDVY:   DVY
01751 004354  LDVZ:   DVZ
01752 000000  PHI:    0
01753 001517          COMPR
01754 000000  SGY:    0
```

APPENDIX B

```
                                     ; ROUTINE TO COMPUTE THE SQUARES OF NUMBERS FOR THE MISSILE
                                     ; FLAME GENERATOR

                                     ; ENTER WITH N IN AC2

                                     ; RETURN WITH LOWER 12 BITS OF N12 IN AC1 AND UPPER 12 BITS
                                       OF N12 IN AC3
01755 054404  SUBM1:  STA    3,RTRN
01756 000404          JMP    .+4
01757 000040  CONS:   32
01760 000020          16
      000001  RTRN:   .BLK+1
01762 151112          MOVL#  2,2,SZC
01763 150400          NEG    2,2
01764 145000          MOV    2,1
01765 102400          SUB    0,0
01766 073301          MUL                 ;SQUARE IN AC1
01767 030771          LDA    2,CONS+1     ;16
01770 073301          MUL                 ;4 H.O. IN AC0, 12 L.O. IN AC1 SHIFTED 4 TO LEFT
01771 115000          MOV    0,3
01772 102400          SUB    0,0
01773 073101          DIV                 ;SHIFT  L.O. BACK TO RIGHT
01774 030107          LDA    2, MSK12
01775 147400          AND    2, 1         ; MASK EACH RETURN TO 12 BITS
01776 157400          AND    2, 3
01777 002762          JMP    @RTRN
      000012          .RDX   10
02000 000200  NUMB:   128
02001 000004          4
02002 000016          14
02003 000000  YDM7:   0
02004 000000  ZDM7:   0
02005 054402  SUBM3:  STA    3,NUMB3
02006 000404          JMP    .+4
02007 000000  NUMB3:  0
02010 000062          50
```

```
02011 000144            100
02012 102400            SUB      0,0
02013 115000            MOV      0,3
02014 125113            MOVL#    1,1,SNC          ;SKIP IF NEG
02015 000403            JMP      .+3
02016 175400            INC      3,3
02017 124400            NEG      1,1
02020 030770            LDA      2,NUMB3+1
02021 147000            ADD      2,1              ;AC1+50 IN AC1
02022 030767            LDA      2,NUMB3+2        ;100 IN AC2
02023 073101            DIV
02024 175004            MOV      3,3,SZR
02025 124400            NEG      1,1
02026 002761            JMP      @NUMB3
02027 054402   SUBM4:   STA      3,NUMB4
02030 000403            JMP      .+3
02031 000000   NUMB4:   0
02032 016246            7334
02033 102400            SUB      0,0
02034 115000            MOV      0,3
02035 125113            MOVL#    1,1,SNC          ;SKIP IF NEG
02036 000403            JMP      .+3
02037 175400            INC      3,3
02040 124400            NEG      1,1
02041 030046            LDA      2,P10.   ;10 IN AC2
02042 073301            MUL                       ;AC1*10
02043 030154            LDA      2,X
02044 073301            MUL                       ;AC1*10*X
02045 030765            LDA      2,NUMB4+1        ;4889
02046 073101            DIV
02047 175004            MOV      3,3,SZR
02050 124400            NEG      1,1
02051 002760            JMP      @NUMB4
02052 054402   SUBM5:   STA      3,NUMB5
02053 000402            JMP      .+2
02054 000000   NUMB5:   0
```

APPENDIX B

```
02055 076400     CLR    3
02056 106132     SSLT   0,1
02057 176000     ADC    3,3       : NOT IN KILL ZONE
02060 124400     NEG    1,1
02061 106533     SSGT   0,1
02062 176000     ADC    3,3       : NOT IN KILL ZONE
02063 002771     JMP    @NUMB5
      000010     .RDX   8
```

APPENDIX B

```
                        ; END OF DRAGON SIMULATOR

02064 060277  SCORE:            INTDS
02065 102000                    ADC      0,0
02066 000403                    JMP      DGNEN
02067 060277  LOST:             INTDS
02070 062400                    CLR      0
02071 040172  DGNEN:            STA      0,ENMOD  ;SAVE END MODE
02072 010173                    ISZ SYSMD         ; SET SYSTEM MODE TO 3 TO INDICATE END MODE
02073 060177                    INTEN
02074 066400                    CLR 1
02075 044151                    STA 1, OMOD1      ; CLEAR THE AIMING ERROR WORD
02076 101005                    MOV 0, 0, SNR     ; SKIP ON NORMAL END OF FLIGHT
02077 000473                    JMP DGEN5
02100 024155             LDA    1,Y
02101 004704             JSR    SUBM3             ;AC1 SET TO (AC1+50)/100
02102 044701             STA    1,YDM7            ;HORIZONTAL DISTANCE OF MISSILE FROM CROSS
                                                   HAIR IN DM
02103 024153             LDA    1,EY
02104 020674             LDA    0,NUMB            ;128
02105 106400             SUB    0,1               ;EY IN LINES RELATIVE TO CROSS HAIR
02106 030120             LDA    2,BCNDY           ;IR WRT HP IN SCAN LINES (HORIZONTAL)
02107 146400             SUB    2,1               ; HORIZONTAL LOCATION OF TARGET WRT CH IN DM
02110 004717             JSR    SUBM4             ; (AC1*10*X)/7334. IN AC1
02111 020672             LDA    0,YDM7
02112 122400             SUB    1,0
02113 040543             STA    0,WORD1
02114 024156             LDA    1,Z
02115 004670             JSR    SUBM3
02116 044666             STA    1,ZDM7            ;VERTICAL DISTANCE OF MISSILE FROM CH IN DM
02117 024152             LDA    1,EZ
02120 020660             LDA    0,NUMB
02121 124400             NEG    1,1
02122 107000             ADD    0,1
02123 030121             LDA    2,BCNDZ           ;VERTICAL DISTANCE IR WRT HP IN SCAN LINES
02124 146400             SUB    2,1
```

AD-A050 809 HARRY DIAMOND LABS ADELPHI MD F/G 5/9

DRAGON MISSILE SIMULATOR.(U)

FEB 78 J J SPELLMAN, A N FILIPOV, R N JOHNSON

UNCLASSIFIED HDL-TR-1835 PM TRADE-TR-77-4 NL

2 OF 2

AD A050809

END

DATE FILMED

4-78

DDC

APPENDIX B

```
02125 004702          JSR     SUBM4               ; (AC1*10*X)/7334. IN AC1
02126 020656          LDA     0,ZDM7
02127 122400          SUB     1,0
02130 040530          STA     0,WORD3

          ; CHECK TO SEE IF VERTICAL IN .LE. +6DM AND .GE. -2DM

02131 076400          CLR     3
02132 024043          LDA     1, P6
02133 030040          LDA     2, P2
02134 150400          NEG     2, 2
02135 106532          SSLE    0, 1                ; SKIP IF VERTICAL MISS WITHIN KILL ZONE
02136 176000          ADC     3, 3
02137 112133          SSGE    0, 2                ; SKIP IF VERTICAL MISS WITHIN KILL ZONE
02140 176000          ADC     3, 3
02141 054516          STA     3, WORD2            ; 0 IF IN KILL ZONE
02142 020514          LDA     0,WORD1             ;HORIZONTAL MISS
02143 024637          LDA     1,NUMB+2            ;14 DM=HORIZONTAL MISS TOLERANCE
02144 004706          JSR     SUBM5
02145 054510          STA     3,WORDO             ;WORDO = 0 IF HORIZONTAL  IN KILL ZONE
```

```
                    ; CHECK FOR HIT, MISS OR ABNORMAL TERMINATION AND SET THE APPROPRIATE FLAG

02146 020507                 LDA 0, WORD0
02147 024510                 LDA 1, WORD2
02150 107004                 ADD 0, 1, SZR      ; SKIP ON A HIT
02151 000417                 JMP DGEN4
02152 062400                 CLR 0
02153 040207                 STA 0, MSBUF+6     ; CLEAR R2H
02154 040210                 STA 0, MSBUF+7     ; CLEAR R2L
02155 020102                 LDA 0, BIT4
02156 040215                 STA 0, MSFLB+4     ; TURN OFF THE FLAME
02157 020136                 LDA 0, HITAV
02160 040140                 STA 0, EXPFG       ; SET (IF ENABLED) THE EXPLOSION FLAG
02161 020145                 LDA 0, TOF         ; GET THE TOF NUMBER OF THE HIT
02162 105220                 MOVZR 0, 1         ; MULT BY 5/4 FOR THE DELAY
02163 125222                 MOVZR 1, 1, SZC    ; ROUND UP IF NECESSARY
02164 125400                 INC 1, 1
02165 107000                 ADD 0, 1
02166 044137                 STA 1, HITFG       ; STORE THE STEP NUMBER FOR THE EXPLOSION SOUND
02167 000403                 JMP DGEN5
02170 102000  DGEN4:         ADC 0, 0
02171 040141                 STA 0, MISFG       ; SET THE MISSED FLAG

                    ; OUTPUT THE SHOT SERIAL NUMBER

02172 020110  DGEN5:         LDA 0, ASCCR
02173 006221                 JSR @ TTCNL        ; CRLF
02174 006222                 JSR @ PRTBL
02175 004010                 TXTR               ; /SHOT # /
02176 024142                 LDA 1, SHTNO
02177 006226                 JSR @ BA.5L        ; OUTPUT THE SHOT NUMBER
02200 010142                 ISZ SHTNO          ; INC FOR NEXT TIME
02201 000401                 NOP                ; FOR SAFETY

                    ; OUTPUT THE DATE
```

APPENDIX B

```
02202 006222    JSR @ PRTBL
02203 004014    TXTS            ; / ON /
02204 024122    LDA 1, MONTH
02205 006225    JSR @ BA.2L     ; OUTPUT THE MONTH
02206 020114    LDA 0, ASCSL
02207 006221    JSR @ TTCNL     ; /
02210 024123    LDA 1, DAY
02211 006225    JSR @ BA.2L     ; OUTPUT THE DAY
02212 020114    LDA 0, ASCSL
02213 006221    JSR @ TTCNL     ; /
02214 024124    LDA 1, YEAR
02215 006225    JSR @ BA.2L     ; OUTPUT THE YEAR
```

APPENDIX B

```
                  ; OUTPUT THE TIME OF DAY

02216 006222            JSR @ PRTBL
02217 004017            TXTT              ; / AT /
02220 024055            LDA 1, P24.
02221 020125            LDA 0, HOURS      ; GET 24. - HOURS
02222 106400            SUB 0, 1          ; HOURS IN AC1
02223 006225            JSR @ BA.2L       ; OUTPUT THE HOUR
02224 020115            LDA 0, ASCCN
02225 006221            JSR @ TTCNL       ; :
02226 024062            LDA 1, P60.
02227 020126            LDA 0, MINS       ; GET 60. - MINS
02230 106400            SUB 0, 1          ; MINUTES IN AC1
02231 006225            JSR @ BA.2L       ; OUTPUT THE MINUTES
02232 020115            LDA 0, ASCCN
02233 006221            JSR @ TTCNL       ; :
02234 024062            LDA 1, P60.
02235 020127            LDA 0, SECS       ; GET 60. - SECONDS
02236 106400            SUB 0, 1          ; SECONDS IN AC1
02237 006225            JSR @ BA.2L       ; OUTPUT THE SECONDS
02240 020110            LDA 0, ASCCR
02241 006221            JSR @ TTCNL       ; CRLF
02242 006221            JSR @ TTCNL       ; CRLF

                  ; INDICATE HIT/MISS AND MISSED DISTANCE FROM CENTER OF KILL ZONE

02243 020172            LDA 0, ENMOD
02244 101004            MOV 0, 0, SZR     ; SKIP IF OPERATOR GOT HOPELESSY LOST
02245 000414            JMP DGENO
02246 006222            JSR @ PRTBL
02247 004125            TXTCC             ; HE GOT LOST
02250 024161            LDA 1, XOUT
02251 006226            JSR @ BA.5L       ; PRINT MISSILE RANGE WHEN HE GOT LOST
02252 006222            JSR @ PRTBL
02253 004145            TXTDD
02254 000413            JMP NEXT          ; SET UP FOR NEXT SHOT
```

APPENDIX B

```
                          ; MISSED DISTANCE STORAGE
02255 000000   WORD0:  0                        ; 0 => IN KILL ZONE IN Y
02256 000000   WORD1:  0                        ; Y MISSED DISTANCE IN DECIMETERS
02257 000000   WORD2:  0                        ; 0 => IN KILL ZONE IN Z
02260 000000   WORD3:  0                        ; Z MISSED DISTANCE IN DECIMETERS
```

```
                                 ; NORMAL TERMINATION

02261 020774  DGEN0:             LDA 0, WORD0
02262 024775                     LDA 1, WORD2
02263 107004                     ADD 0, 1, SZR     ; SKIP IF IT WAS A HIT
02264 000420                     JMP DGEN1
02265 006222                     JSR @ PRTBL
02266 004065                     TXTV              ; /HIT/

02267 020110  NEXT:              LDA 0, ASCCR
02270 006221                     JSR @ TTCNL       ; CRLF
02271 020064                     LDA 0, P67.
02272 040164                     STA 0, TCNT1
02273 020111                     LDA 0, ASCDS
02274 006221                     JSR @ TTCNL       ; OUTPUT 67. -'S
02275 014164                     DSZ TCNT1
02276 000776                     JMP .-2
02277 020110                     LDA 0, ASCCR
02300 006221                     JSR @ TTCNL       ; CRLF
02301 000401                     NOP               ; ***** TEMP ***** CIA
02302 000401                     NOP               ; ***** TEMP ***** STA SYSMD
02303 002247                     JMP @ DGNSL       ; GET READY FOR THE NEXT SHOT

02304 044462  DGEN1:             STA 1, TEMPO
02305 006222                     JSR @ PRTBL
02306 004070                     TXTW              ; /MISSED:  /
02307 024457                     LDA 1, TEMPO
02310 125202                     MOVR 1, 1, SZC    ; SKIP IF HE MISSED IN BOTH AXES
02311 000412                     JMP DGEN2
02312 004420                     JSR YPRNT         ; PRINT THE Y MISSED DISTANCE
02313 020045                     LDA 0, P9.
02314 040452                     STA 0, TEMPO
02315 020117                     LDA 0, ASCSP
02316 006221                     JSR @ TTCNL       ; TAB OVER FOR THE NEXT LINE
02317 014447                     DSZ TEMPO
02320 000776                     JMP .-2
```

APPENDIX B

```
02321 004426               JSR ZPRNT        ; PRINT THE Z MISSED DISTANCE
02322 000745               JMP NEXT

02323 020732  DGEN2:       LDA 0, WORDO
02324 101005               MOV 0, 0, SNR    ; SKIP IF HE MISSED IN THE Y DIRECTION
02325 000403               JMP DGEN3
02326 004404               JSR YPRNT        ; PRINT THE Y MISSED DISTANCE
02327 000740               JMP NEXT

02330 004417  DGEN3:       JSR ZPRNT        ; PRINT THE Z MISSED DISTANCE
02331 000736               JMP NEXT

                    ; SUBROUTINE TO PRINT THE Y MISSED DISTANCE

02332 054434  YPRNT:       STA 3, TEMPO     ; SAVE THE RETURN
02333 024723               LDA 1, WORD1     ; GET THE Y MISSED DISTANCE
02334 125112               MOVL# 1, 1, SZC  ; TAKE THE ABSOLUTE VALUE
02335 124400               NEG 1, 1
02336 006227               JSR @ 33.1L      ; PRINT ITS MAGNITUDE
02337 006222               JSR @ PRTBL
02340 004075               TXTX             ; / M. ON THE/
02341 030422               LDA 2, TXTZL     ; /RIGHT/
02342 024714               LDA 1, WORD1
02343 125102               MOVL 1, 1, SZC   ; CHECK ITS SIGN
02344 030416               LDA 2, TXTYL     ; /LEFT/
02345 006223               JSR @ PRTLL      ; PRINT ITS DIRECTION
02346 002420               JMP @ TEMPO      ; RETURN

                    ; SUBROUTINE TO PRINT THE Z MISSED DISTANCE

02347 054417  ZPRNT:       STA 3, TEMPO     ; SAVE THE RETURN
02350 024710               LDA 1, WORD3     ; GET THE Z MISSED DISTANCE
02351 125112               MOVL# 1, 1, SZC  ; TAKE THE ABSOLUTE VALUE
02352 124400               NEG 1, 1
02353 006227               JSR @ 33.1L      ; OUTPUT THE Z MISSED DISTANCE
02354 030410               LDA 2, TXAAL     ; /HIGH/
```

```
02355 024703                    LDA 1, WORD3
02356 125102                    MOVL 1, 1, SZC     ; CHECK THE SIGN
02357 030406                    LDA 2, TXBBL       ; /LOW/
02360 006223                    JSR @ PRTLL        ; PRINT ITS DIRECTION
02361 002405                    JMP @ TEMPO

02362 004103  TXTYL:  TXTY
02363 004107  TXTZL:  TXTZ
02364 004113  TXAAL:  TXTAA
02365 004120  TXBBL:  TXTBB
02366 000000  TEMPO:  0                            ; MULTI-PURPOSE TEMPORARY STORAGE
```

APPENDIX B

```
                                ; INEQUALITY CHECKS

                          ; CALL:          JSR (S)EQLC
                          ;                <ERROR RETURN ADDRESS>
                          ;                <NORMAL RETURN>

                          ; ENTER WITH NUMBER TO BE CHECKED IN ACO
                          ;          MINIMUM VALUE IN AC1
                          ;          MAXIMUM VALUE IN AC2

                          ; ROUTINES USE ALL FOUR ACCUMULATORS

                          ; USE SEQLC FOR SIGNED NUMBERS, -32768.<= N <= 32767.
                          ;     EQLC FOR UNSIGN NUMBERS , 0 <= N <= 65535.

                          ; RETURN TO <CALL+2> IF (ACO) <= (AC1) <= (AC2)
                          ; OTHERWISE, RETURN THROUGH <CALL+1>

02367 112532  SEQLC:      SSLE 0, 2
02370 003400              JMP @ 0, 3        ; NOT <= MAX
02371 106133              SSGE 0, 1
02372 003400              JMP @ 0, 3        ; NOT >= MIN
02373 001401              JMP 1, 3          ; GOLDEN

02374 112433  EQLC:       SLE 0, 2
02375 003400              JMP @ 0, 3        ; NOT <= MAX
02376 106032              SGE 0, 1
02377 003400              JMP @ 0, 3        ; NOT >= MIN
02400 001401              JMP 1, 3          ; GOLDEN
```

APPENDIX B

```
                        ; 5 DIGIT UNSIGNED BINARY TO ASCII CONVERSION

02401 054530  BNA.5:          STA 3, BNRET     ; SAVE THE RETURN
02402 030042                  LDA 2, P5
02403 050530                  STA 2, BNCTR
02404 034424                  LDA 3, TB10S     ; INDEX FOR TABLE OF POWERS OF 10.
02405 062400  BA5.0:          CLR 0
02406 031400                  LDA 2, 0, 3
02407 073101                  DIV              ; BCD DIGIT IN AC1
02410 030116                  LDA 2, ASC0
02411 147000                  ADD 2, 1         ; ASCII DIGIT IN AC1
02412 045405                  STA 1, 5, 3      ; STORE IN BUFFER
02413 175400                  INC 3, 3         ; INCREMENT FOR NEXT TIME
02414 105000                  MOV 0, 1         ; SET NEXT DIVISOR
02415 014516                  DSZ BNCTR        ; SKIP IF DONE FIVE
02416 000767                  JMP BA5.0
02417 020042                  LDA 0, P5
02420 040513                  STA 0, BNCTR     ; RESET THE LOOP COUNTER FOR TYPING
02421 171000                  MOV 3, 2
02422 021000  BA5.1:          LDA 0, 0, 2      ; GET A CHARACTER
02423 006221                  JSR @ TTCNL      ; TYPE IT
02424 151400                  INC 2, 2         ; INC THE INDEX
02425 014506                  DSZ BNCTR
02426 000774                  JMP BA5.1
02427 002502                  JMP @ BNRET      ; DONE ALL FIVE, RETURN

02430 002431  TB10S:  .+1
02431 023420          10000.
02432 001750           1000.
02433 000144            100.
02434 000012             10.
02435 000001              1.

      000005          .BLK 5                   ; INTERMEDIATE BCD/ASCII BUFFER
```

APPENDIX B

```
                        : ALL KINDS OF SUBROUTINES

                                  : 5 DIGIT ASCII TO BINARY

                                  : CALL:          JSR ASCBN
                                  :                < DELIMITER >
                                  :                < ERROR RETURN ADDRESS>
                                  : NRET:          NOP                         : NORMAL RETURN

                                  : ROUTINE GETS A ASCII NUMBER OF 5 DIGIT MAXIMUM LENGTH AND CONVERTS
                                  : IT TO BINARY IN AC1. LEADING SPACES ARE ALLOWED. THE NUMBER MAYBE
                                  : EITHER POSITIVE OR NEGATIVE. RETURN THROUGH <CALL+2> ON A BAD
                                  : CHARACTER BEFORE THE DELIMETR.
                                  : NORMAL RETURN TO <CALL+3>.

      000400                      .DUSR UH       = 400     ; UPPER HALF WORD SHIFT FOR PARAMETERS

02443 025400  ASCBN:              LDA 1, 0, 3              ; GET THE PARAMETERS
02444 020067                      LDA 0, P177
02445 123400                      AND 1, 0                 ; MASK OFF THE DELIMITER
02446 040464                      STA 0, BNDLM             ; AND SAVE IT
02447 020075                      LDA 0, UPMSK
02450 123700                      ANDS 1, 0                ; MASK OF THE DIGIT COUNT
02451 040462                      STA 0, BNCTR             ; AND SAVE IT
02452 054457                      STA 3, BNRET             ; SAVE THE RETURN POINTER
02453 010456                      ISZ BNRET                ; INCREMENT OVER THE DELIMITER ADDRESS
02454 066400                      CLR 1
02455 044457                      STA 1, BNSGN             ; CLEAR THE SIGN FLAG
02456 044457                      STA 1, BNNUM             ; CLEAR THE CURRENT VALUE HOLDER
02457 004524  ASBNO:              JSR KBCI                 ; GET A CHARACTER
02460 024452                      LDA 1, BNDLM
02461 106415                      SNE 0, 1
02462 000437                      JMP BNEND                ; FOUND THE DELIMETER
02463 024117                      LDA 1, ASCSP
02464 106415                      SNE 0, 1
02465 000772                      JMP ASBNO                ; IGNORE LEADING SPACES
```

```
02466 024451                LDA 1, ASCPS
02467 106415                SNE 0, 1          ; WAS IT A '+'?
02470 000405                JMP ASBN1         ; YES, GET THE NEXT CHAR
02471 024445                LDA 1, ASCMN
02472 106414                SEQ 0, 1          ; WAS IT A '-'?
02473 000406                JMP ASBN2         ; NO, CHECK FOR DIGIT
02474 040440                STA 0, BNSGN      ; YES, SET THE SIGN FLAG
02475 004506    ASBN1:      JSR KBCI          ; GET A CHARACTER
02476 024434                LDA 1, BNDLM
02477 106415                SNE 0, 1          ; WAS IT THE DELIMITER?
02500 000421                JMP BNEND         ; YES
02501 024116    ASBN2:      LDA 1, ASC0
02502 122400                SUB 1, 0          ; AC0 <= CHAR - 60
02503 066400                CLR 1
02504 030045                LDA 2, P9.
02505 004667                JSR EQLC          ; CHECK FOR DIGIT
02506 002527                BNERR             ; BAD CHARACTER, ERROR RETURN
02507 024426                LDA 1,BNNUM       ; LEGAL CHARACTER, GET THE LAST VALUE
02510 030046                LDA 2, P10.
02511 073301                MUL               ; AC1 <= (LAST*10.) + NEW
02512 044423                STA 1, BNNUM      ; STORE THE NEW VALUE
02513 014420                DSZ BNCTR         ; SKIP IF GOT MAX NUMBER OF DIGITS
02514 000761                JMP ASBN1
02515 004466                JSR KBCI          ; ALL DIGITS FOUND, LOOK FOR DELIMITER
02516 024414                LDA 1, BNDLM
02517 106414                SEQ 0, 1          ; THIS CHAR MUST BE DELIM FOR GOOD RETURN
02520 000407                JMP BNERR         ; SORRY, FELLA
02521 024414    BNEND:      LDA 1, BNNUM      ; GET NUMBER (ABSOLUTE VALUE)
02522 020412                LDA 0, BNSGN      ; GET SIGN FLAG
02523 101004                MOV 0, 0, SZR     ; SIGN THE NUMBER
02524 124400                NEG 1, 1
02525 010404                ISZ BNRET         ; SET RETURN ADDRESS
02526 002403                JMP @ BNRET       ; RETURN
02527 034402    BNERR:      LDA 3, BNRET      ; ERROR RETURN
02530 003400                JMP @ 0, 3        ; JUMP THROUGH CALL+2
```

```
02531 000000  BNRET:  0
02532 000000  BNDLM:  0
02533 000000  BNCTR:  0
02534 000000  BNSGN:  0
02535 000000  BNNUM:  0
02536 000055  ASCMN:  "-
02537 000053  ASCPS:  "+
```

APPENDIX B

```
; KEYBOARD, GET A BUFFER, INTERRUPT

                        ; CALL:       JSR KBBI         ; GET A BUFFER
                        ;             <N>              ; N CHARACTERS OR LESS LONG
                        ;             <ADR*2>          ; AND STORE IT STARTING AT ADR
                        ; RET:        NOP              ; RETURN HERE

02540 021400  KBBI:     LDA 0, 0 3       ; GET THE CHARACTER COUNT
02541 040437            STA 0, KBB.A
02542 021401            LDA 0, 1, 3      ; GET THE ADDRESS POINTER
02543 040436            STA 0, KBB.B
02544 054436            STA 3, KBB.C     ; SAVE THE RETURN POINTER
02545 004436  KBB.0:    JSR KBCI         ; GET A CHARACTER IN AC0
02546 024110            LDA 1, ASCCR
02547 106415            SNE 0, 1
02550 076400            CLR 3    ; FOUND A CR FLAG
02551 030430            LDA 2, KBB.B     ; GET TWICE THE ADDRESS
02552 010427            ISZ KBB.B        ; INCREMENT FOR NEXT TIME
02553 151220            MOVZR 2, 2       ; FORM ADDRESS WITH BYTE POINTER IN CARRY
02554 025000            LDA 1, 0, 2      ; GET THE CURRENT WORD
02555 101003            MOV 0, 0, SNC    ; SKIP IF STORING UPPER BYTE THIS TIME
02556 000403            JMP KBB.1
02557 101300            MOVS 0, 0        ; MOVE CHARACTER TO UPPER HALF
02560 123000            ADD 1, 0         ; ADD THE LAST BYTE
02561 041000  KBB.1:    STA 0, 0, 2      ; STORE THE BYTE(S)
02562 175005            MOV 3, 3, SNR
02563 000410            JMP KBB.3        ; FOUND A CR BEFORE MAX STRING LENGTH
02564 014414            DSZ KBB.A        ; SKIP IF MAX LENGTH INPUT
02565 000760            JMP KBB.0
02566 020110            LDA 0, ASCCR     ; WENT THE FULL ROUTE WITHOUT A CR
02567 041001            STA 0, 1, 2
02570 004437            JSR TTCNI        ; FORCE A CR & LF
02571 034411  KBB.2:    LDA 3, KBB.C
02572 001402            JMP 2, 3         ; RETURN
02573 101003  KBB.3:    MOV 0, 0, SNC    ; SKIP IF UPPER BYTE WAS STORED
02574 000775            JMP KBB.2
```

APPENDIX B

```
02575 062400                CLR 0           ; SET AN EOB MARKER
02576 041001                STA 0, 1, 2
02577 000772                JMP KBB.2

02600 000000   KBB.A:   0                   ; CHARACTER COUNT
02601 000000   KBB.B:   0                   ; TWICE THE ADDRESS
02602 000000   KBB.C:   0                   ; RETURN POINTER
```

APPENDIX B

```
                        ; KEYBOARD, GET A CHARACTER, INTERRUPT

                                ; CALL:         JSR KBCI        ; GET A CHARACTER IN ACO
                                ; RET:          NOP             ; RETURN HERE

                                ; ROUTINE DOES THE FOLLOWING
                                ;       1. GETS A CHARACTER IN KBBLK+2
                                ;       2. ECHOES LEGAL CHARACTERS
                                ;       3. IGNORES ILLEAGAL CHARACTERS

                                ; USES ALL 4 ACCUMUALTORS

02603 102000   KBCI:            ADC 0, 0
02604 040175                    STA 0, KBBLK      ; REQUEST A CHARACTER
02605 020176                    LDA 0, KBBLK+1
02606 101005                    MOV 0, 0, SNR     ; SKIP IF ONE RECEIVED
02607 000776                    JMP .-2
02610 062400                    CLR 0
02611 040176                    STA 0, KBBLK+1    ; CLEAR THE RECEIVED FLAG
02612 020177                    LDA 0, KBBLK+2    ; FETCH THE CHARACTER
02613 024110                    LDA 1, ASCCR
02614 106414                    SEQ 0, 1          ; SKIP IF FOUND A CARRIAGE RETURN
02615 000405                    JMP KBCI1
02616 171000                    MOV 3, 2          ; SAVE THE CALLING PC
02617 004410                    JSR TTCNI         ; ECHO THE CR & PRINT AN LF
02620 020110                    LDA 0, ASCCR      ; RESTORE A CR IN ACO FOR THE CALLING ROUTINE
02621 001000                    JMP 0, 2          ; RETURN
02622 024117   KBCI1:           LDA 1, ASCSP
02623 106032                    SGE 0, 1
02624 000757                    JMP KBCI          ; ILLEAGAL CHARACTER, IGNORE IT
02625 000402                    JMP TTCNI         ; LEGAL CHARACTER, ECHO AND RETURN

02626 000012   ASCLF:  12                         ; ASCII LINE FEED CODE
```

APPENDIX B

```
                              ; TELETYPE PRINT A CHARACTER, NO INTERRUPT

                                ; CALL:          JSR TTCNI       ; TYPE THE CHARACTER IN ACO
                                ; RET:           NOP             ; RETURN HERE

                                ; ROUTINE PRINTS THE CHARACTER IN ACO. IF THE CHARACTER WAS A
                                ; CR, ROUTINE ALSO DOES AN LF.

                                ; ROUTINE USES ACO, AC1, AC3

02627 063511   TTCNI:           SKPBZ TTO        ; WAIT FOR TTO READY
02630 000777                    JMP .-1
02631 061111                    DOAS 0, TTO
02632 024110                    LDA 1, ASCCR
02633 106414                    SEQ 0, 1
02634 001400                    JMP 0, 3         ; RETURN
02635 020771                    LDA 0, ASCLF     ; FOUND A CR, DO AN LF
02636 000771                    JMP TTCNI

                              ; PRINT A BUFFER ON THE TELETYPE

                                ; CALL:          JSR PRTBF       ; TYPE THE BUFFER WHOSE SA FOLLOWS
                                ;                <ADR>
                                ; RET:           NOP             ; RETURN HERE

                                ; ROUTINE PRINTS PACKED ASCII CHARACTERS FROM THE ADDRESS IN
                                ; <CALL+1> UNTIL A NULL BYTE IS FOUND

                                ; ROUTINE USES ALL FOUR ACCUMULATORS

02637 031400   PRTBF:           LDA 2, 0, 3      ; GET THE BUFFER ADDRESS
02640 175400                    INC 3, 3
02641 054415   PRTLN:           STA 3, PRTRT
02642 021000   PRTBO:           LDA 0, 0, 2      ; GET 2 BYTES
02643 024072                    LDA 1, P377
02644 123405                    AND 1, 0, SNR    ; MASK OFF UPPER HALF SKIP IF NO EOB FOUND
```

APPENDIX B

```
02645 002411              JMP @ PRTRT     ; EOB FOUND, RETURN
02646 004761              JSR TTCNI       ; PRINT THE CHARACTER
02647 021000              LDA 0, 0, 2     ; RE-FETCH THE SAME 2 BYTES
02650 151400              INC 2, 2        ; SET THE POINTER FOR THE NEXT 2 BYTES
02651 024075              LDA 1, UPMSK
02652 123705              ANDS 1, 0, SNR  ; MASK OFF THE LOWER HALF, SKIP IF NO EOB
02653 002403              JMP @ PRTRT     ; EOB FOUND, RETURN
02654 004753              JSR TTCNI       ; PRINT THE CHARACTER
02655 000765              JMP PRTBO       ; KEEP GOING UNTIL EOB FOUND

02656 000000   PRTRT:  0                  ; RETURN ADDRESS STORED HERE
```

APPENDIX B

```
                        ; ROUTINE TO EVOKE A YES OR NO RESPONSE

                                  ; CALL:       JSR YORN        ; GET THE RESPONSE
                                  ; YESRT:      NOP             ; RETURN HERE ON 'YES'
                                  ; NORT:       NOP             ; RETURN HERE ON 'NO'

                                  ; ROUTINE GETS A 'Y' OR 'N' FROM THE KEYBOARD AND COMPLETES
                                  ; THE WORD. IF A BAD CHARACTER IS TYPED, DOES A CRLF AND
                                  ; TRIES AGAIN

02657 054424  YORN:               STA 3, YRN.A     ; SAVE RETURN POINTER
02660 004757  YRN.0:              JSR PRTBF
02661 003763                      TXTN             ; /(Y OR N)? /
02662 004721  YRN.1:              JSR KBCI         ; GET A CHARACTER
02663 024421                      LDA 1, YRN.B
02664 106415                      SNE 0, 1
02665 000407                      JMP YRN.2        ; HE TYPED A 'Y'
02666 024417                      LDA 1, YRN.C
02667 106415                      SNE 0, 1
02670 000407                      JMP YRN.3        ; HE TYPED AN 'N'
02671 020415                      LDA 0, YRN.D     ; HE BLEW IT
02672 004735                      JSR TTCNI        ; DO CR & LF
02673 000765                      JMP YRN.0        ; AND TRY AGAIN

02674 004743  YRN.2:              JSR PRTBF
02675 003725                      TXTI             ; /ES<15>/
02676 002405                      JMP @ YRN.A      ; RETURN TO CALL+1

02677 004740  YRN.3:              JSR PRTBF
02700 003727                      TXTJ             ; /O<15>/
02701 010402                      ISZ YRN.A
02702 002401                      JMP @ YRN.A      ; RETURN TO CALL+2

02703 000000  YRN.A:    0                          ; RETURN STORAGE
02704 000131  YRN.B:    "Y
02705 000116  YRN.C:    "N
02706 000015  YRN.D:    15
```

```
                         : PRINT OUT RESTART MESSAGES AND DO THE PROPER RESTART

02707 020411  PRSTM:          LDA 0, AROWP     : ASCII IP
02710 030253                  LDA 2, DIAGL     : DIAGNOSTIC RESTART AND THEN POWER RESTART
02711 000403                  JMP RSTMO
02712 020407  DRSTM:          LDA 0, AROWR     : ASCII IR
02713 030247                  LDA 2, DGNSL     : DRAGON RESTART ADDRESS
02714 004713  RSTMO:          JSR TTCNI        : OUTPUT THE LOWER BYTE
02715 101300                  MOVS 0, 0
02716 004711                  JSR TTCNI        : OUTPUT THE UPPER BYTE
02717 001000                  JMP 0, 2         : DO THE PROPER RESTART

02720 050136  AROWP:   050136
02721 051136  AROWR:   051136

                         : TWO DIGIT UNSIGNED BINARY TO ASCII CONVERSION, ENTER WITH NUMBER
                           IN AC1

02722 054414  BNA.2:          STA 3, BNASR     : SAVE THE RETURN
02723 030046                  LDA 2, P10.
02724 062400                  CLR 0
02725 073101                  DIV              : MS IN AC1, LS IN ACO
02726 030116                  LDA 2, ASCO
02727 147000                  ADD 2, 1
02730 113000                  ADD 0, 2
02731 121000                  MOV 1, 0
02732 004675                  JSR TTCNI        : OUTPUT THE MS CHAR
02733 141000                  MOV 2, 0
02734 004673                  JSR TTCNI        : OUTPUT THE LS´CHAR
02735 002401                  JMP @ BNASR

02736 000000  BNASR:   0

                         : SUBROUTINE TO PRINT AN UNSIGNED NUMBÉR IN F3.1 FORMAT

02737 054417  BN3.1:          STA 3, BNART     : SAVE THE RETURN
02740 062400                  CLR 0
```

APPENDIX B

```
02741 030046                     LDA 2, P10.
02742 073101                     DIV              ; 2 MS DIGITS IN AC1
02743 040411                     STA 0, BNAST     ; SAVE THE LS DIGIT
02744 004756                     JSR BNA.2        ; PRINT THE 2 MS DIGITS
02745 020410                     LDA 0, ASCPT     ; ASCII DECIMAL POINT
02746 004661                     JSR TTCNI
02747 020116                     LDA 0, ASC0      ; ASCII 0
02750 024404                     LDA 1, BNAST
02751 123000                     ADD 1, 0         ; FORM LS CHARACTER
02752 004655                     JSR TTCNI        ; PRINT IT
02753 002403                     JMP @ BNART      ; RETURN

02754 000000    BNAST:  0
02755 000056    ASCPT:  ".
02756 000000    BNART:  0
```

APPENDIX B

```
                          ; TIME OF DAY ROUTINE

                    : ROUTINE MAINTAINS 4 COUNTERS THAT ARE USED TO COUNT TIME OF DAY
                    : THE LEAST SIGNIFICANT COUNTER HAS A FULL SCALE VALUE OF 1 SECOND.
                    ; THE RESOLUTION OF THIS COUNTER IS A FUNCTION OF THE DATARATE.
                    ; THE OTHER 3 COUNTERS ARE HOURS, MINUTES, AND SECONDS AND ARE
                    : STORED AS (FULL SCALE - VALUE).

02757 014420  TOD:      DSZ TDDRC       ; DECREMENT THE DATA RATE COUNTER
02760 001400            JMP 0, 3        ; HAS NOT GONE TO ZERO, RETURN
02761 020076            LDA 0, SECND
02762 040415            STA 0, TDDRC    ; RESET THE DATA RATE COUNTER
02763 014127            DSZ SECS        ; AND DECREMENT THE SECONDS COUNTER
02764 001400            JMP 0, 3
02765 020062            LDA 0, P60.
02766 040127            STA 0, SECS     ; RESET THE SECONDS COUNTER
02767 014126            DSZ MINS        ; AND DECREMENT THE MINUTES COUNTER
02770 001400            JMP 0, 3
02771 040126            STA 0, MINS     ; RESET THE MINUTES COUNTER
02772 014125            DSZ HOURS       ; AND DECREMENT THE HOURS COUNTER
02773 001400            JMP 0, 3
02774 020055            LDA 0, P24.
02775 040125            STA 0, HOURS    ; RESET THE HOURS COUNTER
02776 001400            JMP 0, 3        ; AND RETURN
02777 000000  TDDRC:    0
```

APPENDIX B

```
                                       : SUBROUTINE TO COMPUTE THE AIMING ERROR WORD

03000 054502  SUBM7:   STA      3,SAVER
03001 062400           CLR      0
03002 040151           STA      0,OMOD1       ;OMOD1 IS NOW CLEAR
03003 020134           LDA      0, AUDIO
03004 101005           MOV      0, 0, SNR   ; SKIP IF AIDES ARE ENABLED
03005 001400           JMP      0, 3
03006 020153           LDA      0,EY
03007 024120           LDA      1,BCNDY       ;IR HORIZONTAL POSTION WRT LOS IN SCAN LINES
03010 030070           LDA      2,P200        ;128
03011 133000           ADD      1,2
03012 142400           SUB      2,0
03013 040471           STA      0,EYL         ;EYL=EY-(BIRY+128)
03014 020152           LDA      0,EZ
03015 024121           LDA      1,BCNDZ
03016 030070           LDA      2,P200        ;128
03017 107000           ADD      0,1
03020 132400           SUB      1,2
03021 050464           STA      2,EZL         ;EZL=128-(EZ+BIRZ)
03022 020146           LDA      0,STEP
03023 034460           LDA      3,TIME
03024 025400           LDA      1,0,3
03025 106533           SSGT     0,1           ;SKIP    IF STEP > AC1
03026 000420           JMP      BIGE
03027 175400  UPS:     INC      3,3
03030 025400           LDA      1,0,3         ;AC1=45,78,120...OR 330,10000
03031 106132           SSLT     0,1           ;SKIP IF STEP LT TME IN AC1
03032 000775           JMP      UPS
03033 020045           LDA      0,P9.
03034 117000           ADD      0,3           ;CHANGE ADDRESS BY 9
03035 171000           MOV      3,2           ;VERTICAL ERROR LIMIT ADDRESS IN AC2
03036 024131           LDA      1,TGSPD
03037 125004           MOV      1,1,SZR       ;SKIP IF TGSPD=0
03040 117000           ADD      0,3           ;HORIVONTAL ERROR LIMIT IN AC3
03041 025400           LDA      1,0,3
```

```
03042 044445          STA    1,HESL              ;HORIZONTAL ERROR LIMIT IN SCAN LINES
03043 025000          LDA    1,0,2
03044 044442          STA    1,VESL              ;VERTICAL ERROR LIMIT IN SCAN LINES
03045 000411          JMP    ALARM
03046 020442   BIGE:  LDA    0,HESL+1                  ;75
03047 040440          STA    0,HESL
03050 020441          LDA    0,VESL+3            ;40
03051 040435          STA    0,VESL
03052 000404          JMP    ALARM
03053 020102   RING:  LDA    0,BIT4
03054 040151          STA    0,OMOD1
03055 000441          JMP    AIM
```

```
03056 020426  ALARM: LDA   0,EYL
03057 024430         LDA   1,HESL
03060 106132         SSLT  0,1       ;SKIP IF EYL<HESL
03061 000772         JMP   RING
03062 124400         NEG   1,1
03063 106533         SSGT  0,1       ;SKIP   IF EYL>-HESL
03064 000767         JMP   RING
03065 020420         LDA   0,EZL
03066 124400         NEG   1,1
03067 030146         LDA   2,STEP
03070 036413         LDA   3,@TIME
03071 156532         SSLE  2,3              ;SKIP IF STEP<=45
03072 024414         LDA   1,VESL
03073 124400         NEG   1,1
03074 106533         SSGT  0,1              ;SKIP IF EZL>-VESL
03075 000756         JMP   RING
03076 024410         LDA   1,VESL
03077 122533         SSGT  1,0              ;SKIP VESL>EZL
03100 000753         JMP   RING
03101 000415         JMP   AIM
      000001  SAVER: .BLK  1
03103 004423  TIME:  TME
03104 000000  EYL:   0
03105 000000  EZL:   0
03106 000000  VESL:  0
03107 000000  HESL:  0
      000012         .RDX 10
03110 000113         75
03111 000050         40
03112 000016         14
03113 000004         4
03114 000077         63
03115 002030         1048
      000010         .RDX 8
03116 076400  AIM:   CLR   3
03117 024765         LDA   1,EYL
```

```
03120 125112     MOVL#   1,1,SZC        ;SKIP    IF      POSITIVE
03121 124400     NEG     1,1
03122 030130     LDA     2,TGRNG
03123 062400     CLR     0
03124 073301     MUL                    :EYL*TGRNG
03125 030074     LDA     2, P733.
03126 000401     NOP
03127 073101     DIV                    ; EYL*TGRNG/733.
03130 030762     LDA     2,HESL+3       ;14 =HORIZONTAL LIMIT
03131 132132     SSLT    1,2            :SKIP ERROR<14
03132 034763     LDA     3,HESL+6       ;1048 THAT IS 1 IN BIT 5
03133 044751     STA     1,EYL
03134 024751     LDA     1,EZL
03135 125112     MOVL#   1,1,SZC        ;SKIP    IF POSITIVE
03136 124400     NEG     1,1
03137 030130     LDA     2,TGRNG
03140 062400     CLR     0
03141 073301     MUL
03142 030074     LDA     2, P733.
03143 000401     NOP
03144 073101     DIV                    ; EZL*TGRNG/733.
03145 030746     LDA     2,HESL+4       ;4=VERTICAL ERROR LIMIT
03146 132132     SSLT    1,2            ;SKIP    IF AC1<AC2
03147 034746     LDA     3,HESL+6       ;1048=1 INBIT 5
03150 030151     LDA     2,OMOD1
03151 157000     ADD     2,3            ;COMBINE BIT4 AND BIT 5
03152 054151     STA     3,OMOD1
03153 034731     LDA     3,EYL
03154 030740     LDA     2,HESL+5       ;63
03155 172532     SSLE    3,2
03156 000407     JMP     MAXX
03157 132532     SSLE    1,2
03160 000405     JMP     MAXX
03161 137000     ADD     1,3
03162 137000     ADD     1,3
03163 137000     ADD     1,3            ;3*ABS(Z)+ABS(Y)
```

```
03164 172532            SSLE    3,2           ;SKIP IF AC3 LT 63
03165 155000  MAXX:     MOV     2,3
03166 030151            LDA     2,OMOD1       ; BIT 4 AND 5
03167 173000            ADD     3,2
03170 050151            STA     2,OMOD1
03171 002711            JMP     @ SAVER

                                ; DRAGON I/O CONTROL SYSTEM

                        ; POWER FAILED !!!!!!!!!!

03172 062677  PFAIL:            IORST
03173 040551                    STA 0, TACO   ; SAVE THE REGISTERS, JUST IN CASE
03174 044551                    STA 1, TAC1
03175 050551                    STA 2, TAC2
03176 054551                    STA 3, TAC3
03177 175200                    MOVR 3, 3
03200 054550                    STA 3, TCAR
03201 020000                    LDA 0, 0
03202 040547                    STA 0, TPC
03203 020040                    LDA 0, P2     ; SET POWER RESTART ADDRESS
03204 040000                    STA 0, 0
03205 063077                    HALT          ; AND KILL IT
```

APPENDIX B

```
                              ; TELETYPE KEYBOARD SERVICE

                         ; UPON RECEIPT OF A TTI INTERRUPT, PERFORMS THE FOLLOWING

                         ; 1. READS A CHARACTER IN ACO & STORES IT IN KBBLK+2
                         ;    IF KBBLK WAS SET. ALSO SETS KBBLK+1
                         ; 2. MASKS OFF THE PARITY BIT
                         ; 3. RESTARTS THE SYSTEM ON A IP
                         ; 4. RESTARTS THE TRAINER ON A IR

03206 060610  KBDSV:          DIAC 0, TTI      ; READ THE CHARACTER AND CLEAR
03207 024175                  LDA 1, KBBLK     ; CHECK THE REQUEST FLAG
03210 131005                  MOV 1, 2, SNR    ; SKIP IF CHARACTER WAS REQUESTED
03211 000405                  JMP KBDSO        ; WAS NOT, SEE IF IT WAS A RESTART
03212 066400                  CLR 1
03213 044175                  STA 1, KBBLK     ; CLEAR THE REQUEST FLAG
03214 124000                  COM 1, 1
03215 044176                  STA 1, KBBLK+1   ; SET THE RECEIVED FLAG
03216 024067  KBDSO:          LDA 1, P177
03217 123400                  AND 1, 0         ; MASK OFF THE PARITY BIT
03220 024423                  LDA 1, CTRLP
03221 106415                  SNE 0, 1
03222 000407                  JMP PRRST        ; FOUND A POWER RESTART REQUEST
03223 024421                  LDA 1, CTRLR
03224 106415                  SNE 0, 1
03225 000406                  JMP DGRST        ; FOUND A TRAINER RESTART REQUEST
03226 151004                  MOV. 2, 2, SZR
03227 040177                  STA 0, KBBLK+2   ; ONLY STORE IS CHARACTER WAS REQUESTED
03230 002417                  JMP @ STROL      ; RESTORE

03231 030414  PRRST:          LDA 2, PRSML     ; POWER RESTART MESSAGE
03232 000404                  JMP RSTO
03233 030413  DGRST:          LDA 2, DRSML     ; TRAINER RESTART MESSAGE
03234 062400                  CLR 0
03235 040176                  STA 0, KBBLK+1   ; CLEAR THE RECEIVED FLAG JUST IN CASE
03236 060277  RSTO:           INTDS            ; DISABLE WHILE REMASKING
```

```
03237 020101                    LDA 0, IMASK     ; REMASK
03240 062077                    MSKO 0
03241 060177                    INTEN            ; RE-ENABLE INTERRUPTS
03242 001000                    JMP 0, 2         ; CONTINUE

03243 000020   CTRLP:   20
03244 000022   CTRLR:   22
03245 002707   PRSML:   PRSTM
03246 002712   DRSML:   DRSTM
03247 003450   STROL:   STMRO
```

APPENDIX B

```
                          : INTERRUPT MONITOR

03250 040474  IMON:               STA 0, TAC0     ; STORE THE REGISTERS
03251 044474                      STA 1, TAC1
03252 050474                      STA 2, TAC2
03253 054474                      STA 3, TAC3
03254 175200                      MOVR 3, 3
03255 054473                      STA 3, TCAR
03256 020000                      LDA 0, 0        ; GET THE INTERRUPTED PC
03257 040472                      STA 0, TPC
03260 063777                      SKPDZ CPU
03261 000711                      JMP PFAIL       ; POWER FAIL, SAVE & HALT
03262 102000                      ADC 0, 0        ; RE-ENABLE FOR PFAIL ONLY
03263 062177                      ENMSK 0
03264 063742                      SKPDZ DIO
03265 000470                      JMP STMSV       ; SYSTEM (DIO) INTERRUPT
03266 063710                      SKPDZ TTI
03267 000717                      JMP KBDSV       ; TELETYPE KEYBOARD INTERRUPT
                                                  ; ****************************************
03270 061477                      INTA 0          ; ***** GET THE OFFENDING DEVICE CODE *****
03271 063077                      HALT            ; *****      SHOULD NEVER DO THIS      *****
                                                  ; ****************************************
03272 000002                      JMP PRST        ; GO TO THE POWER UP SEQUENCE

                          : SYSTEM NOT IN RUN MODE, FORCE THE MISSILE/FLAME OFF

03273 030140  MFOT1:              LDA 2, EXPFG
03274 151004                      MOV 2, 2, SZR   ; CHECK THE EXPLOSION FLAG
03275 000410                      JMP MFOT2       ; IT WAS SET
03276 020102  MFOT7:              LDA 0, BIT4     ; MISSILE/FLAME OFF BIT
03277 061142                      DOAS 0, DIO
03300 063642                      SKPDN DIO
03301 000777                      JMP .-1
03302 014450                      DSZ TCNT        ; SKIP IF DONE
03303 000774                      JMP MFOT7+1
03304 000474                      JMP MFOT5       ; CONTINUE
```

APPENDIX B

```
                    : FLASH THE DISPLAY TO INDICATE A HIT

03305 014446  MFOT2:       DSZ EXPCT          ; DECREMENT THE EXPLOSION COUNT
03306 000406               JMP MFOT3
03307 030076               LDA 2, SECND       ; DONE, RESET THE COUNTER
03310 050443               STA 2, EXPCT
03311 072400               CLR 2
03312 050140               STA 2, EXPFG       ; CLEAR THE FLAG
03313 000763               JMP MFOT7
03314 020437  MFOT3:       LDA 0, EXPCT
03315 101200               MOVR 0, 0
03316 101200               MOVR 0, 0
03317 101203               MOVR 0, 0, SNC     ; SKIP IF TIME TO FLASH ON
03320 000756               JMP MFOT7
03321 020210               LDA 0, MSBUF+7     ; GET R2L
03322 105140               MOVOL 0, 1         ; MULT BY 2 & INC
03323 030107               LDA 2, MSK12
03324 147400               AND 2, 1           ; MASK TO 12 BITS
03325 146414               SEQ 2, 1           ; SKIP IF REACHED FULL SCALE
03326 000403               JMP MFOT4
03327 040210               STA 0, MSBUF+7     ; STORE THE NEW VALUE
03330 000440               JMP MFOT6          ; AND OUTPUT
03331 044210  MFOT4:       STA 1, MSBUF+7     ; STORE THE NEW VALUE
03332 000436               JMP MFOT6          ; AND OUTPUT

                    : SYSTEM NOT IN RUN MODE, CHECK THE TRIGGER

03333 024144  MDIOO:       LDA 1, TRGEN
03334 125005               MOV 1, 1, SNR      ; SKIP IF TRIGGER ENABLED
03335 000510               JMP STMRS
03336 101213               MOVR# 0, 0, SNC    ; SKIP IF TRIGGER BIT SET
03337 000506               JMP STMRS
03340 010173               ISZ SYSMD          ; IT WAS, SET THE SYSTEM MODE TO 2 TO
                                                INDICATE RUN MODE
03341 062400               CLR 0
03342 040144               STA 0, TRGEN       ; CLEAR THE TRIGGER ENABLE
```

```
03343 000471                   JMP STMS0

                    : MISCELLANEOUS STORAGE

03344 000000   TAC0:   0                         ; TEMPORARY REGISTER STORAGE
03345 000000   TAC1:   0
03346 000000   TAC2:   0
03347 000000   TAC3:   0
03350 000000   TCAR:   0
03351 000000   TPC:    0
03352 000000   TCNT:   0                         ; TEMPORARY COUNTER
03353 000076   EXPCT:  SECND                     ; EXPLOSION COUNTER
03354 000000   DRDIV:  0                         ; DATA RATE DIVIDER
```

APPENDIX B

```
                       ; SYSTEM (DIO) SERVICE

03355 010777  STMSV:           ISZ DRDIV        ; INCREMENT THE DATA RATE COUNTER TO DIVIDE
03356 000401                   NOP              ; DATA RATE DOWN TO 30HZ
03357 060242  MFOUT:           NIOC DIO
03360 020100                   LDA 0, UNPLS     ; FAKE IOPLS
03361 061142                   DOAS 0, DIO      ; SELECT THE MISSILE CHANNEL
03362 020051                   LDA 0, P13.
03363 040767                   STA 0, TCNT      ; SET UP A LOOP COUNTER
03364 030040                   LDA 2, P2
03365 034173                   LDA 3, SYSMD
03366 156414                   SEQ 2, 3         ; SKIP IF SYSTEM IN RUN MODE
03367 000704                   JMP MFOT1        ; NOT IN RUN MODE, FORCE MISSILE/FLAME OFF
03370 020200  MFOT6:           LDA 0, MSFMB     ; GET MISSILE/FLAME BUFFER SA-1
03371 040024                   STA 0, INOTP     ; STORE IN I/O POINTER (AUTO INDEX)
03372 022024  MFOTO:           LDA 0, @ INOTP   ; GET A DATA WORD
03373 061142                   DOAS 0, DIO      ; OUTPUT AND INC TO NEXT REGISTER
03374 063642                   SKPDN DIO
03375 000777                   JMP .-1          ; ***** SHOULDN'T NEED THIS *****
03376 014754                   DSZ TCNT         ; SKIP IF DONE ALL 13.
03377 000773                   JMP MFOTO
      000000  MFOT5:

                       ; READ THE BEACON POSITION

03400 006235  BCNIN:           JSR @ BECNL      ; READ THE BEACON POSITION
03401 003405                   BCNIO            ; IGNORE THE SEEK/CHECK BIT
03402 003405                   BCNIO            ; DON'T STORE ON BAD DATA
03403 040152                   STA 0, EZ        ; STORE IN CURRENT POSITION BUFFER
03404 044153                   STA 1, EY
03405 020747  BCNIO:           LDA 0, DRDIV     ; GET THE DATA RATE DIVIDER
03406 101203                   MOVR 0, 0, SNC   ; SKIP ON ODD VALUE
03407 000436                   JMP STMRS        ; EVEN VALUE DENOTES INTERMEDIATE INTERRUPT
```

```
000000  MODIO:

                      ; FORM THE THRUSTER MODE WORD

03410 004454               JSR MFNS

                      ; DO THE MODE I/O

03411 020070               LDA 0, P200
03412 024100               LDA 1, UNPLS
03413 107000               ADD 0, 1
03414 065142               DOAS 1, DIO          ; SELECT UNIT 2 REGISTER O
03415 061142               DOAS 0, DIO          ; STROBE IMODO
03416 063642               SKPDN DIO
03417 000777               JMP .-1
03420 060442               DIA 0, DIO           ; READ THE INPUT MODE
03421 040147               STA 0, IMODO
03422 024150               LDA 1, OMODO
03423 065142               DOAS 1, DIO          ; OUTPUT THE THRUSTER WORD
03424 063642               SKPDN DIO
03425 000777               JMP .-1
03426 024151               LDA 1, OMOD1
03427 065142               DOAS 1, DIO          ; OUTPUT THE ERROR WORD
03430 034173               LDA 3, SYSMD
03431 030040               LDA 2, P2
03432 172032               SGE 3, 2             ; SKIP IF SYSTEM IN RUN OR END MODE
03433 000700               JMP MDIOO

                      ; INCREMENT THE TIME OF FLIGHT

03434 030040  STMSO:       LDA 2, P2
03435 034173               LDA 3, SYSMD
03436 172033               SLT 3, 2             ; DON'T SKIP IF IN RUN OR END MODE
03437 010145               ISZ TOF              ; INC TOF (30 HZ COUNTER)
03440 000401               NOP                  ; FOR SAFETY
03441 156414               SEQ 2, 3             ; SKIP IF IN RUN MODE
```

APPENDIX B

```
03442 000403            JMP STMRS         ; NOPE, JUST RETURMN

                  ; SET THE RESTART ADDRESS TO GET OUT OF THE WAIT LOOP

03443 020420            LDA 0, SMLPL
03444 040705            STA 0, TPC

                  ; RESTORE ROUTINE

03445 020077  STMRS:    LDA 0, UNCLR      ; FAKE IOCLR
03446 061142            DOAS 0, DIO       ; DIO CONTROLLER READY FOR NEXT 60 HZ INTERRUPT
03447 006216            JSR @ TODL        ; INCREMENT TIME OF DAY
03450 034700  STMRO:    LDA 3, TCAR       ; RESTORE THE REGISTERS
03451 175100            MOVL 3, 3
03452 034675            LDA 3, TAC3
03453 030673            LDA 2, TAC2
03454 024671            LDA 1, TAC1
03455 060277            INTDS             ; DISABLE WHILE REMASKING
03456 020101            LDA 0, IMASK      ; REMASK FOR DIO, TTI, PFAIL
03457 062077            MSKO 0
03460 020664            LDA 0, TAC0
03461 060177            INTEN             ; RE-ENABLE INTERRUPTS
03462 002667            JMP @ TPC               ; AND RETURN

03463 001046  SMLPL:  STRT1               ; SIMULATOR LOOP LINK
```

APPENDIX B

```
                              ; FORM THE THRUSTER NOISE WORD

03464 054511  MFNS:           STA 3, MFNSR      ; SAVE THE RETURN
03465 020135                  LDA 0, VIDEO
03466 024136                  LDA 1, HITAV
03467 107014                  ADD# 0, 1, SZR    ; SKIP IF NO NOISE OPTIONS ARE ENABLED
03470 000403                  JMP MFNS0         ; GO FIND OUT WHAT'S ENABLED
03471 040150                  STA 0, DMODO      ; CLEAR THE WORD
03472 002503                  JMP @ MFNSR       ; RETURN
03473 076400  MFNS0:          CLR 3             ; CONTROL BITS WILL BE HELD HERE
03474 101005                  MOV 0, 0, SNR     ; SKIP IF MISSILE NOISES ARE ENABLED
03475 000430                  JMP MFNS2         ; GO CHECK FOR HIT/MISS
03476 020145                  LDA 0, TOF        ; WHEN TOF IS
03477 024052                  LDA 1, P15.       ; GREATER THAN 0.5 SEC OR
03500 030060                  LDA 2, P45.       ; LESS THAN 1.5 SEC
03501 006231                  JSR @ EQLCL       ; DO THE INEQUALITY CHECK
03502 003505                  MFNS1             ; CHECK FOR THRUSTERS
03503 034105                  LDA 3, BIT7       ; GET THE LAUNCH CONTROL BIT
03504 000402                  SKIP

                            ; CHECK FOR THRUSTER TIME

03505 076400  MFNS1:          CLR 3
03506 020166                  LDA 0, DFMIC
03507 024056                  LDA 1, P30.
03510 106415                  SNE 0, 1          ; SKIP IF THE FIRST THRUSTER HAS FIRED
03511 000414                  JMP MFNS2
03512 024170                  LDA 1, DFMOC      ; GET THE OUTPUT COUNT
03513 122533                  SSGT 1, 0         ; SKIP IF THE OUTPUT COUNT .GE. INPUT COUNT
03514 000411                  JMP MFNS2         ; NO, GO CHECK FOR HIT/MISS
03515 022167                  LDA 0, @ DFMOP    ; GET A VALUE
03516 024145                  LDA 1, TOF
03517 106414                  SEQ 0, 1          ; CHECK AGAINST TOF
03520 000405                  JMP MFNS2         ; NOT TIME TO SOUND IT, CHECK FOR HIT/MISS
03521 014170                  DSZ DFMOC         ; DECREMENT THE COUNT, NO MATTER IF IT SKIPS
03522 010167                  ISZ DFMOP         ; DECREMENT THE POINTER TO THE NEXT VALUE
```

```
03523 030102          LDA 2, BIT4      ; LOAD THE THRUSTER CONTROL BIT
03524 157000          ADD 2, 3

                ; CHECK FOR HIT/MISS

03525 020136 MFNS2: LDA 0, HITAV
03526 101005          MOV 0, 0, SNR
03527 000414          JMP MFNS3        ; HIT/MISS DISABLED, CHECK TO SEE IF NOISE VALUE NEEDED
03530 020141          LDA 0, MISFG
03531 101004          MOV 0, 0, SZR
03532 000433          JMP MFNS4        ; HE MISSED
03533 020137          LDA 0, HITFG
03534 101005          MOV 0, 0, SNR
03535 000406          JMP MFNS3        ; HE DID NOT HIT
03536 024145          LDA 1, TOF
03537 106414          SEQ 0, 1                  ; CHECK AGAINST TIME OF FLIGHT
03540 000403          JMP MFNS3        ; NOT TIME TO SOUND IT
03541 030103          LDA 2, BIT5      ; GET THE HIT CONTROL BIT
03542 157000          ADD 2, 3         ; ADD TO ANY PREVIOUS BITS

                ; CHECK TO SEE IF A NOISE NUMBER IS NEEDED. FORM IT IF NECESSARY

03543 175005 MFNS3: MOV 3, 3, SNR    ; SKIP IF ANY OF THE CONTROL BITS ARE SET
03544 000424          JMP MFNS5        ; NOPE, EXIT
03545 024145          LDA 1, TOF
03546 020053          LDA 0, P22.
03547 106502          SUBL 0, 1, SZC   ; TOF - 22. IS TIME FROM FIRST MOTION
03550 126401          SUB 1, 1, SKP    ; KEEP IT AT 0 UNTIL TOF .GE. 22.
03551 125220          MOVZR 1, 1       ; SHIFT IT BACK DOWN
03552 062400          CLR 0
03553 030046          LDA 2, P10.
03554 073101          DIV
03555 151220          MOVZR 2, 2
03556 112033          SLT 0, 2
03557 125400          INC 1, 1         ; ROUND UP (TOF-22.)/10.
03560 030106          LDA 2, MSK6
```

```
03561 147400                 AND 2, 1         : JUST FOR SAFETY
03562 167000                 ADD 3, 1         : ADD THE CONTROL BITS
03563 044150                 STA 1, DMODO     : STORE THE NEW MODE WORD
03564 002411                 JMP @ MFNSR      : AND RETURN

                  : HE MISSED

03565 030104  MFNS4:         LDA 2, BIT6      : GET THE MISSED CONTROL BIT
03566 050150                 STA 2, DMODO
03567 002406                 JMP @ MFNSR      : EXIT

03570 020150  MFNS5:         LDA 0, DMODO     : GET THE LAST VALUE
03571 024106                 LDA 1, MSK6
03572 123400                 AND 1, 0         : BE SURE NO CONTROL BITS ARE SET
03573 040150                 STA 0, DMODO     :CLEAR THE NOISE WORD
03574 002401                 JMP @ MFNSR

03575 000000  MFNSR:  0
```

APPENDIX B

```
                                   : TEXT BUFFERS
         000000   TXTA:                                        : 'DATE (MM/DD/YY) - '
   03576 040504             .TXT 'DA
   03577 042524   TE
   03600 024040    (
   03601 046515   MM
   03602 042057   /D
   03603 027504   D/
   03604 054531   YY
   03605 020051   )
   03606 020055   -
   03607 000000   '

         000000   TXTB:                                        : /TIME (HH:MM:SS:) - /
   03610 044524             .TXT /TI
   03611 042515   ME
   03612 024040    (
   03613 044110   HH
   03614 046472   :M
   03615 035115   M:
   03616 051523   SS
   03617 020051   )
   03620 020055   -
   03621 000000   /

         000000   TXTC:                                        : /GUNNER ID - /
   03622 052507             .TXT /GU
   03623 047116   NN
   03624 051105   ER
   03625 044440    I
   03626 020104   D
   03627 020055   -
   03630 000000   /

          00000   TXTD:                                        : /TARGET RANGE (M) = /
```

```
03631 040524          .TXT /TA
03632 043522   RG
03633 052105   ET
03634 051040    R
03635 047101   AN
03636 042507   GE
03637 024040    (
03640 024515   M)
03641 036440    =
03642 000040    /

      000000   TXTE:                          ; /TARGET CROSSING SPEED (KPH) = /
03643 040524          .TXT /TA
03644 043522   RG
03645 052105   ET
03646 041440    C
03647 047522   RO
03650 051523   SS
03651 047111   IN
03652 020107   G
03653 050123   SP
03654 042505   EE
03655 020104   D
03656 045450   (K
03657 044120   PH
03660 020051   )
03661 020075   =
03662 000000   /

      000000   TXTF:                          ; /TARGET ELEVATION (M) = /
03663 040524          .TXT /TA
03664 043522   RG
03665 052105   ET
03666 042440    E
03667 042514   LE
03670 040526   VA
```

```
03671 044524   TI
03672 047117   ON
03673 024040    (
03674 024515   M)
03675 036440    =
03676 000040    /

      000000   TXTG:                                : /AUDIO AIMING AIDS /
03677 052501          .TXT /AU
03700 044504   DI
03701 020117   O
03702 044501   AI
03703 044515   MI
03704 043516   NG
03705 040440    A
03706 042111   ID
03707 020123   S
03710 000000   /

      000000   TXTH:                                : /MISSILE IMAGE ENABLED /
03711 044515          .TXT /MI
03712 051523   SS
03713 046111   IL
03714 020105   E
03715 046511   IM
03716 043501   AG
03717 020105   E
03720 047105   EN
03721 041101   AB
03722 042514   LE
03723 020104   D
03724 000000   /

      000000   TXTI:                                : /ES<15>/
03725 051505          .TXT /ES
03726 000015   <15>/
```

```
      000000  TXTJ:                          ; /O<15>/
03727 006517          .TXT /O<15>
03730 000000  /

      000000  TXTK:                          ; /INSTRUCTOR ID - /
03731 047111          .TXT /IN
03732 052123  ST
03733 052522  RU
03734 052103  CT
03735 051117  OR
03736 044440   I
03737 020104  D
03740 020055  -
03741 000000  /

      000000  TXTL:                          ; /CLEAR SKY /
03742 046103          .TXT /CL
03743 040505  EA
03744 020122  R
03745 045523  SK
03746 020131  Y
03747 000000  /

      000000  TXTM:                          ; 'HIT/MISS INDICATION '
03750 044510          .TXT 'HI
03751 027524  T/
03752 044515  MI
03753 051523  SS
03754 044440   I
03755 042116  ND
03756 041511  IC
03757 052101  AT
03760 047511  IO
03761 020116  N
03762 000000  '
```

```
            000000  TXTN:                                   ; /(Y OR N)? /
03763 054450                .TXT /(Y
03764 047440   O
03765 020122  R
03766 024516  N)
03767 020077  ?
03770 000000  /

            000000  TXTO:                                   ; /NEW PARAMETERS /
03771 042516                .TXT /NE
03772 020127  W
03773 040520  PA
03774 040522  RA
03775 042515  ME
03776 042524  TE
03777 051522  RS
04000 000040   /

            000000  TXTP:                                   ; /? YES<15>/
04001 020077                .TXT /?
04002 042531  YE
04003 006523  S<15>
04004 000000  /

            000000  TXTQ:                                   ; /? NO<15>/
04005 020077                .TXT /?
04006 047516  NO
04007 000015  <15>/

            000000  TXTR:                                   ; /SHOT # /
04010 044123                .TXT /SH
04011 052117  OT
04012 021440   #
04013 000040   /
```

```
      000000  TXTS:                 ; / ON /
04014 047440        .TXT / O
04015 020116  N
04016 000000  /

      000000  TXTT:                 ; / AT /
04017 040440        .TXT / A
04020 020124  T
04021 000000  /

      000000  TXTU:                 ; / ***** DRAGON TRAINER, HARRY DIAMOND LABORATORIES.
                                    ; REV (REV#).00 *****<15><15>/
      000001        .DUSR   RV0       = REV/10.

      000012        .DUSR   RV1       = REV/10.*10.
04022 025040        .TXT / *
04023 025052  **
04024 025052  **
04025 042040   D
04026 040522  RA
04027 047507  GO
04030 020116  N
04031 051124  TR
04032 044501  AI
04033 042516  NE
04034 026122  R,
04035 044040   H
04036 051101  AR
04037 054522  RY
04040 042040   D
04041 040511  IA
04042 047515  MO
04043 042116  ND
04044 046040   L
04045 041101  AB
04046 051117  OR
```

```
04047 052101  AT
04050 051117  OR
04051 042511  IE
04052 026123  S,
04053 051040   R
04054 053105  EV
04055 030440   <RV0+60>
04056 027061  <REV-RV1+60>.
04057 030060  00
04060 025040   *
04061 025052  **
04062 025052  **
04063 006415  <15><15>
04064 000000  /
      000000  TXTV:                                 : /HIT<15>/
04065 044510           .TXT /HI
04066 006524  T<15>
04067 000000  /

      000000  TXTW:                                 : /MISSED:  /
04070 044515           .TXT /MI
04071 051523  SS
04072 042105  ED
04073 020072  :
04074 000040   /

      000000  TXTX:                                 : / M. TO THE/
04075 046440           .TXT / M
04076 020056  .
04077 047524  TO
04100 052040   T
04101 042510  HE
04102 000000  /

      000000  TXTY:                                 : / LEFT<15>/
04103 046040           .TXT / L
```

```
04104 043105  EF
04105 006524  T<15>
04106 000000  /

      000000  TXTZ:                                ; / RIGHT<15>/
04107 051040          .TXT / R
04110 043511   IG
04111 052110   HT
04112 000015  <15>/

      000000  TXTAA:                               ; / M. HIGH<15>/
04113 046440          .TXT / M
04114 020056   .
04115 044510   HI
04116 044107   GH
04117 000015  <15>/

      000000  TXTBB:                               ; / M. LOW<15>/
04120 046440          .TXT / M
04121 020056   .
04122 047514   LO
04123 006527  W<15>
04124 000000  /

      000000  TXTCC:                               ; /FLIGHT TERMINATED AT RANGE OF /
04125 046106          .TXT /FL
04126 043511   IG
04127 052110   HT
04130 052040    T
04131 051105   ER
04132 044515   MI
04133 040516   NA
04134 042524   TE
04135 020104   D
04136 052101   AT
04137 051040    R
```

```
04140 047101  AN
04141 042507  GE
04142 047440   O
04143 020106  F
04144 000000  /

      000000  TXTDD:                                   ; / M. DUE TO OPERATOR EPROR<15>/
04145 046440            .TXT / M
04146 020056  .
04147 052504  DU
04150 020105  E
04151 047524  TO
04152 047440   O
04153 042520  PE
04154 040522  RA
04155 047524  TO
04156 020122  R
04157 051105  ER
04160 047522  RO
04161 006522  R<15>
04162 000000  /

      000000  TXTEE:                                   ; /<15>** MTEST **<15>/
04163 025015            .TXT /<15>*
04164 020052  *
04165 046440   M
04166 042524  TE
04167 052123  ST
04170 020040
04171 025052  **
04172 000015  <15>/

      000000  TXTFF:                                   ; /<15>** BTEST **<15>VERT   HORZ<15>/
04173 025015            .TXT /<15>*
04174 020052  *
04175 041040   B
```

```
04176 042524   TE
04177 052123   ST
04200 020040
04201 025052   **
04202 053015   <15>V
04203 051105   ER
04204 020124   T
04205 020040
04206 047510   HO
04207 055122   RZ
04210 000015   <15>/

      000000   TXTGG:                              ; /<15>**  ALIGN  **<15>/
04211 025015            .TXT /<15>*
04212 020052   *
04213 040440    A
04214 044514   LI
04215 047107   GN
04216 020040
04217 025052   **
04220 000015   <15>/

      000000   TXTHH:                        ; /<15>**  SOUND TESTS  **<15>/
04221 025015            .TXT /<15>*
04222 020052   *
04223 051440    S
04224 052517   OU
04225 042116   ND
04226 052040    T
04227 051505   ES
04230 051524   TS
04231 020040
04232 025052   **
04233 000015   <15>/

                        ; DYNAMIC TEXT BUFFERS
```

APPENDIX B

```
000006  TCHID:   .BLK 6                      : INSTRUCTOR ID
000006  GNRID:   .BLK 6                      : GUNNER ID

                 : FLAME TIME DELAY BUFFER

000036  DFLMB:   .BLK 30.
```

```
                        ; SINE LOOK-UP TABLE
                        ; SIN(PHI*143) IN 2 DEGREE STEPS

      000012            .RDX 10

      000001  DVY:      .BLK 1
04307 000000            0
04310 000005            5
04311 000012            10
04312 000017            15
04313 000024            20
04314 000031            25
04315 000036            30
04316 000042            34
04317 000047            39
04320 000054            44
04321 000060            48
04322 000065            53
04323 000072            58
04324 000077            63
04325 000103            67
04326 000107            71
04327 000113            75
04330 000120            80
04331 000124            84
04332 000130            88
04333 000134            92
04334 000137            95
04335 000143            99
04336 000147            103
04337 000152            106
04340 000155            109
04341 000160            112
04342 000163            115
04343 000166            118
04344 000171            121
```

```
04345 000173          123
04346 000176          126
04347 000200          128
04350 000202          130
04351 000204          132
04352 000206          134
04353 000210          136
04354 000211   DVZ:   137
```

APPENDIX B

```
                        ; COSINE LOOK-UP TABLE
                        ; COS(PHI*143) IN 2 DEGREE STEPS
04355 000217            143
04356 000217            143
04357 000216            142
04360 000216            142
04361 000215            141
04362 000214            140
04363 000213            139
04364 000212            138
04365 000211            137
04366 000210            136
04367 000206            134
04370 000204            132
04371 000202            130
04372 000200            128
04373 000176            126
04374 000173            123
04375 000171            121
04376 000166            118
04377 000163            115
04400 000160            112
04401 000155            109
04402 000152            106
04403 000147            103
04404 000143            99
04405 000137            95
04406 000134            92
04407 000130            88
04410 000124            84
04411 000120            80
04412 000113            75
04413 000107            71
04414 000103            67
04415 000077            63
```

```
04416 000072          58
04417 000065          53
04420 000060          48
04421 000054          44
04422 000047          39

      000010          .RDX 8
```

```
      000012          .RDX 10
04423 000055   TME:   45
04424 000116          78
04425 000170          120
04426 000242          162
04427 000314          204
04430 000366          246
04431 000440          288
04432 000512          330
04433 023420          10000
04434 000012          10
04435 000011          9
04436 000010          8
04437 000007          7
04440 000006          6
04441 000005          5
04442 000004          4
04443 000003          3
04444 000003          3
04445 000031          25
04446 000027          23
04447 000024          20
04450 000022          18
04451 000017          15
04452 000015          13
04453 000012          10
04454 000010          8
04455 000010          8
      000010          .RDX 8
```

APPENDIX B

```
                                : TEST PROGRAMS

                          ; MISSILE SPOT GENERATOR

                  : GENERATES A MISSILE SPOT AT THE CENTER OF THE SCREEN

                  : INSTRUCTIONS
                  : 1. SET SWITCHES TO S.A. OF THIS PROGRAM
                  : 2. RESET AND START
                  : 3. SWITCHES MAY THE BE SET TO THE DESIRED RADIUS (LOW ORDER ONLY)
                  : 4. SET SWITCH 0 TO RETURN TO DEBUGGER

      005000      .LOC 5000

05000 060277  MTEST:      INTDS
05001 102000              ADC 0, 0          ; MASK OUT ALL INTERRUPTS BUT POWER FAIL
05002 062077              MSKO 0
05003 060177              INTEN             ; AND ENABLE INTERRUPTS
05004 006222              JSR @ PRTBL       ; PRINT THE TITLE OF THIS TEST
05005 004163              TXTEE
05006 060477  MTSTO:      READS 0
05007 101112              MOVL# 0, 0, SZC ; SKIP IF ANOTHER RADIUS DESIRED
05010 000410              JMP MTST2         ; RETURN TO DEBUGGER
05011 024107              LDA 1, MSK12
05012 123400              AND 1, 0          ; MASK OFF UPPER 4 BITS
05013 040417              STA 0, MTSB+10    ; STORE IN THE MISSILE TEST BUFFER
05014 004527              JSR HZ60          ; WAIT FOR A 60HZ INTERRUPT
05015 030405              LDA 2, MTSB       ; TEST BUFFER SA-1
05016 004532              JSR MISFM         ; OUTPUT THE MISSILE ONLY
05017 000767              JMP MTSTO         ; SEE IF MORE TO BE DONE
05020 060277  MTST2:      INTDS             ; DISABLE THE INTERRUPTS
05021 002254              JMP @ DEBUG       ; AND RETURN TO THE DEBUGGER

05022 005022  MTSB:   .                     ; MISSILE TEST BUFFER
05023 007600          7600                  ; -X IN 12 BITS
05024 007600          7600                  ; -Y IN 12 BITS
```

```
05025 000004        4       ; X**2H
05026 000000        0       ; X**2L
05027 000004        4       ; Y**2H
05030 000000        0       ; Y**2L
05031 000000        0       ; R**2H
05032 000000        0       ; R**2L
05033 000000        0
05034 000000        0
05035 000000        0
05036 000000        0
05037 004000     4000       ; FLAME OFF BIT
```

APPENDIX B

```
                              : BEACON TEST PROGRAM

                    : READS THE BEACON AND OUTPUTS THE HORIZONTAL AND VERTICLE POSITION
                    : ON THE TELETYPE

             : INSTRUCTIONS
             : 1. SET THE SWITCHES TO THE S.A. OF THIS PROGRAM
             : 2. RESET AND START
             : 3. STRIKE ANY KEY ON THE TTY KEYBOARD TO GET AN OUTPUT
             : 4. RAISING SWITCH 1 AND STRIKING A KEY WILL GIVE A CONTINUOUS OUTPUT
             : 5. RAISING SWITCH 0 WILL RETURN TO THE DEBUGGER

05040 060277  BTEST:          INTDS
05041 102000                  ADC 0, 0          : MASK OUT ALL INTERRUPTS EXCEPT POWER FAIL
05042 062077                  MSKO 0
05043 060177                  INTEN             : ENABLE INTERRUPTS
05044 006222                  JSR @ PRTBL       : PRINT THE TITLE OF THIS TEST
05045 004173                  TXTFF
05046 060477  BTSTO:          READS 0
05047 101102                  MOVL 0, 0, SZC
05050 000426                  JMP BTST1         : DONE, RETURN TO THE DEBUGGER
05051 101102                  MOVL 0, 0, SZC
05052 000404                  JMP BTST2         : REQUESTED A CONTINUOUS OUTPUT
05053 063610                  SKPDN TTI         : SINGLE OUTPUT, WAIT FOR THE PROMPT
05054 000777                  JMP .-1
05055 060210                  NIOC TTI          : CLEAR TTI FOR THE NEXT PROMPT
05056 004465  BTST2:          JSR HZ60          : WAIT FOR A 60 HZ INTERRUPT
05057 004426                  JSR BECON         : READ THE BEACON POSTION
05060 005056                  BTST2             : SEEK CYCLE RETURN
05061 005100                  BTST3             : BAD DATA RETURN

                    : GOOD DATA, PRINT IT AND GO BACK

05062 040421                  STA 0, TBVRT      : SAVE THE VERTICAL POSITION
05063 044421                  STA 1, TBHRZ      : SAVE THE HORIZONTAL POSITION
05064 105000                  MOV 0, 1          : PRINT THE VERTICAL POSITION
```

```
05065 006226          JSR @ BA.5L     ; OUTPUT THE VERTICLE POSITION (DEC)
05066 020117          LDA 0, ASCSP
05067 006221          JSR @ TTCNL
05070 006221          JSR @ TTCNL
05071 024413          LDA 1, TBHRZ    ; GET THE HORIZONTAL POSITION
05072 006226          JSR @ BA.5L     ; OUTPUT THE HORIZONTAL POSITION (DEC)
05073 020110          LDA 0, ASCCR    ; CRLF
05074 006221          JSR @ TTCNL
05075 000751          JMP BTST0

05076 060277  BTST1:  INTDS
05077 002254          JMP @ DEBUG     ; RETURN TO THE DEBUGGER

              ; FOUND BAD DATA AND CHECK COMPLETE, RING THE BELL AND RETURN

05100 020044  BTST3:  LDA 0, P7
05101 006221          JSR @ TTCNL     ; RING THE BELL
05102 000744          JMP BTST0       ; GET THE NEXT PROMPT

05103 000000  TBVRT:  0
05104 000000  TBHRZ:  0
```

APPENDIX B

```
                              ; DIAGNOSTIC SUBROUTINES

                     ; READ THE BEACON

                              ; CALL:     JSR BECON
                              ;           <SEEK RETURN ADDRESS>
                              ;           <BAD DATA RETURN ADDRESS>
                              ;           BAD DATA BIT NOT SUPPORTED IN CURRENT HARDWARE
                              ; NRET:     NOP

                              ; ALL ACCUMULATORS USED
                              ; VERTICAL POSITION RETURNED IN AC0
                              ; HORIZONTAL POSITION RETURNED IN AC1

05105 020435  BECON:          LDA 0, BCNSL      ; BECON SELECT CODE
05106 061142                  DOAS 0, DIO
05107 072400                  CLR 2
05110 071142                  DOAS 2, DIO       ; STROBE THE VERTICAL
05111 063642                  SKPDN DIO
05112 000777                  JMP .-1
05113 060442                  DIA 0, DIO        ; READ THE VERTICAL
05114 071142                  DOAS 2, DIO       ; STROBE THE HORIZONTAL
05115 063642                  SKPDN DIO
05116 000777                  JMP .-1
05117 064442                  DIA 1, DIO
05120 101223                  MOVZR 0, 0, SNC   ; SKIP ON GOOD DATA
05121 000407                  JMP BECNO
05122 050416                  STA 2, BDDTA      ; CLEAR THE BAD DATA COUNTER
05123 101220                  MOVZR 0, 0        ; SHIFT OUT THE CHECK BIT
05124 030415                  LDA 2, MSK8
05125 143400                  AND 2, 0          ; MASK TO 8 BITS
05126 147400                  AND 2, 1
05127 001402                  JMP 2, 3          ; NORMAL RETURN
05130 101223  BECNO:          MOVZR 0, 0, SNC   ; SKIP ON CHECK COMPLETE
05131 003400                  JMP @ 0, 3        ; SEEK CYCLE RETURN
05132 030407                  LDA 2, MSK8
```

```
05133 143400                AND 2, 0         ; MASK TO 8 BITS
05134 147400                AND 2, 1
05135 010403                ISZ BDDTA        ; INCREMENT THE BAD DATA COUNTER
05136 000401                NOP
05137 001402                JMP 2, 3         ; AND RETURN

05140 000000   BDDTA:  0
05141 000377   MSK8:   377
05142 140100   BCNSL:  140100

         ; WAIT FOR A 60 HZ INTERRUPT FROM THE DIO, NON INTERRUPT ENABLED ROUTINE

05143 020077   HZ60:        LDA 0, UNCLR     ; FAKE IOCLR
05144 061142                DOAS 0, DIO
05145 063642                SKPDN DIO        ; WAIT FOR THE INTERRUPT
05146 000777                JMP .-1
05147 001400                JMP 0, 3
```

APPENDIX B

```
                              ; MISSILE FLAME OUTPUT ROUTINE

                    ; ENTER WITH BUFFER S.A.-1 IN AC2
05150 050024  MISFM:        STA 2, INOTP    ; STORE IN THE I/O AUTO INDEX LOCATION
05151 030100                LDA 2, UNPLS
05152 071142                DOAS 2, DIO     ; SELECT THE MISSILE/FLAME UNIT
05153 030051                LDA 2, P13.
05154 050410                STA 2, MSFCT    ; SET UP A LOOP COUNTER
05155 032024  MISFO:        LDA 2, @ INOTP  ; GET A WORD
05156 071142                DOAS 2, DIO
05157 063642                SKPDN DIO
05160 000777                JMP .-1
05161 014403                DSZ MSFCT       ; SKIP IF DONE
05162 000773                JMP MISFO
05163 001400                JMP 0, 3

05164 000000  MSFCT:  0

                    ; ROUTINE READS IMODO ( THE TRIGGER WORD)

05165 020410  IMOIN:        LDA 0, IMDSL
05166 061142                DOAS 0, DIO     ; SELECT UNIT 2, REGISTER 0
05167 062400                CLR 0
05170 061142                DOAS 0, DIO     ; STROBE UNIT 2, REGISTER 0
05171 063642                SKPDN DIO
05172 000777                JMP .-1
05173 060442                DIA 0, DIO      ; READ IT
05174 001400                JMP 0, 3

05175 140200  IMDSL:  140200
```

APPENDIX B

```
                                   : TRACKER ALIGNMENT PROGRAM

                         : INSTRUCTIONS
                         : 1. SET THE SWITCHES TO THE S.A. OF THIS PROGRAM
                         : 2. RESET AND START
                         : 3. A SMALL CIRCLE WILL APPEAR ON THE TRACKER SCREEN
                         :    ALIGN THE CROSS-HAIRS WITH THE SPOT AND PUUL THE TRIGGER
                         : 4. A CIRCLE AT THE I.R. BEACON POSTION WILL APPEAR ON THE TRACKER SCREEN
                         : 5. CAREFULLY AIM THE TRACKER AT THE CENTER OF THE AIMING POINT
                         : 6. IF THE CIRCLE INTERSECTS THE CROSS-HAIRS, PULL THE TRIGGER
                         : 7. IF THE CIRCLE DOES NOT INTERSECT THE CROSS-HAIRS, ADJUST THE
                         :    I.R. CAMERA UNTIL THE CIRCLE DOES.
                         :    THE SECOND TRIGGER PULL ENDS THE PROGRAM AND RETURNS TO THE DEBUGGER
                         :    LIFTING SWITCH ZERO AT ANY TIME, WILL ABORT AND RETURN TO SYSTEM

      000200                       .DUSR YMID = 128.
      000200                       .DUSR ZMID = 128.

05176 060277  ALIGN:               INTDS
05177 102000                       ADC 0, 0
05200 062177                       ENMSK 0          ; ENABLE POWER FAIL INTERRUPTS
05201 006222                       JSR @ PRTBL
05202 004211                       TXTGG            ; /<15>** ALIGN  **<15>/
05203 004740                       JSR HZ60         ; WAIT FOR A 60 HZ INTERRUPT
05204 030471                       LDA 2, CENTR
05205 004743                       JSR MISFM        ; OUTPUT A SPOT AT THE MIDPOINT OF THE SCREEN

                              ; TRIGGER PULL DENOTES CROSSHAIR ALIGNMENT DONE

05206 060477                       READS 0
05207 101102                       MOVL 0, 0, SZC   ; SEE IF HE WANTS TO ABORT
05210 002254                       JMP @ DEBUG      ; YES, RETURN TO SYSTEM
05211 004732                       JSR HZ60
05212 004753                       JSR IMOIN        ; GET THE TRIGGER WORD
05213 101203                       MOVR 0, 0, SNC   ; SKIP ON TRIGGER
05214 000776                       JMP .-2
```

```
05215 004726            JSR HZ60
05216 004747            JSR IMOIN          ; GET IT AGAIN
05217 101202            MOVR 0, 0, SZC     ; SKIP ON NO TRIGGER TO DEBOUNCE THE SWITCH
05220 000775            JMP .-3
                    ; NOW DISPLAY THE BEACON POSITION

05221 060477  ALGNO:    READS 0
05222 101102            MOVL 0, 0, SZC     ; SEE IF HE WANTS TO ABORT
05223 002254            JMP @ DEBUG        ; YES, RETURN TO SYSTEM
05224 004717            JSR HZ60           ; WAIT FOR 60 HZ INTERRUPT
05225 004660            JSR BECON          ; READ THE BEACON POSITION
05226 005221            ALGNO              ; IGNORE THE SEEK/CHECK BIT
05227 005266            ALGN1              ; FLASH THE FLAME ON BAD DATA
05230 040653            STA 0, TBVRT       ; SAVE VERTICAL POSITION
05231 044653            STA 1, TBHRZ       ; SAVE HORIZONTAL POSITION
05232 100400            NEG 0, 0
05233 030107            LDA 2, MSK12
05234 143400            AND 2, 0           ; -Y IN 12 BITS
05235 040460            STA 0, YBNEG
05236 124400            NEG 1, 1
05237 147400            AND 2, 1           ;-Z IN 12 BITS
05240 044454            STA 1, ZBNEG
05241 030642            LDA 2, TBVRT
05242 006233            JSR @ SBM1L        ; SQUARE IT AND RETURN IN 12 BIT WORDS
05243 044454            STA 1, ZB2L
05244 054452            STA 3, ZB2H
05245 030637            LDA 2, TBHRZ
05246 006233            JSR @ SBM1L
05247 044452            STA 1, YB2L
05250 054450            STA 3, YB2H
05251 030442            LDA 2, BCNBF
05252 004676            JSR MISFM          ; DISPLAY THE BEACON POSITION
05253 004712            JSR IMOIN          ; GET THE TRIGGER WORD
05254 101203            MOVR 0, 0, SNC
05255 000744            JMP ALGNO          ; NO TRIGGER, READ THE BEACON AGAIN
```

APPENDIX B

```
                                 ; NOW COMPUTE THE BEACON-AIMING POINT DISPLACEMENT

05256 020070                          LDA 0, P200
05257 024625                          LDA 1, TBHRZ
05260 106400                          SUB 0, 1          ; BCNDY = TBHRZ - 128.
05261 044120                          STA 1, BCNDY
05262 024621                          LDA 1, TBVRT
05263 122400                          SUB 1, 0          ; BCNDZ = 128. - TBVRT
05264 040121                          STA 0, BCNDZ
05265 002254                          JMP @ DEBUG       ; DONE

                                 ; FLASH THE FLAME ON BAD DATA

05266 020041          ALGN1:          LDA 0, P4
05267 040441                          STA 0, FMWDT
05270 030423                          LDA 2, BCNBF
05271 004657                          JSR MISFM         ; OUTPUT THE MISSILE WITH FLAME
05272 020102                          LDA 0, BIT4       ; TURN IT OFF FOR NEXT TIME
05273 040435                          STA 0, FMWDT
05274 000725                          JMP ALGN0         ; GO TRY AGAIN

05275 005275          CENTR:     .
05276 007600                     -ZMID&7777
05277 007600                     -YMID&7777
05300 000004                     ZMID*ZMID/10000
05301 000000                     ZMID*ZMID&7777
05302 000004                     YMID*YMID/10000
05303 000000                     YMID*YMID&7777
05304 000000                     0
05305 000004                     4
05306 000000                     0
05307 000000                     0
05310 000000                     0
05311 000000                     0
05312 004000                     4000
```

APPENDIX B

```
05313 005313  BCNBF:  .
05314 000000  ZBNEG:  0
05315 000000  YBNEG:  0
05316 000000  ZB2H:   0
05317 000000  ZB2L:   0
05320 000000  YB2H:   0
05321 000000  YB2L:   0
05322 000000          0
05323 000044          44
05324 000000          0
05325 000000          0
05326 000000          0
05327 000000          0
05330 004000  FMWDT:  4000
```

APPENDIX B

```
                          ; SOUND TESTS

                      ; INSTRUCTIONS
                      ; 1. SET THE SWITCHES TO THE S.A. OF THIS PROGRAM
                      ; 2. RESET AND START
                      ; 3. LIFTING SWITCH 0 WILL RETURN TO THE SYSTEM
                      ; 4. LIFTING SWITCH 1 WILL RUN THE MISSILE SOUNDS TEST
                      ;    LOWERING SWITCH 1 WILL RUN THE AIMING ERROR TEST

                      ; MISSILE SOUNDS TEST SWITCH ASSIGNMENTS

                      ;         4       GENERATES A THRUSTER SOUND
                      ;         5       GENERATES A HIT INDICATION
                      ;         6       GENERATES A MISSED INDICATION
                      ;         7       GENERATES A LAUNCH SOUND
                      ;         10-15   VALUE BITS

                      ; AIMING ERROR TEST SWITCH ASSIGNMENTS

                      ;         4       GENERATES AN ALARM TONE
                      ;         5       GENERATES AN ERROR TONE
                      ;         10-15   VALUE BITS

05331 060277  STEST:            INTDS
05332 102000                    ADC 0, 0
05333 062177                    ENMSK 0          ; ENABLE POWER FAIL INTERRUPTS
05334 006222                    JSR @ PRTBL
05335 004221                    TXTHH            ; /SOUND TESTS/
05336 060477  STSTO:            READS 0          ; GET A TEST COMMAND FROM THE S.R.
05337 101112                    MOVL# 0, 0, SZC
05340 002254                    JMP @ DEBUG      ; RETURN TO THE SYSTEM
05341 024107                    LDA 1, MSK12
05342 107400                    AND 0, 1         ; MASK OFF THE DIO CONTROL BITS
05343 030077                    LDA 2, UNCLR
05344 113404                    AND 0, 2, SZR    ; CHECK THE TEST TYPE
05345 000405                    JMP STST1        ; DO THE MISSILE TEST
```

APPENDIX B

```
                                ; AIMING ERROR TEST

05346 020426                    LDA 0, OM1SL
05347 061142                    DOAS 0, DIO      ; SELECT UNIT 2 REGISTER 2
05350 065142                    DOAS 1, DIO      ; OUTPUT THE TEST WORD
05351 000765                    JMP STST0        ; GET THE NEXT TEST COMMAND

                                ; MISSILE SOUND TEST

05352 006237  STST1:            JSR @ HZ60L      ; WAIT FOR A VERTICAL BLANKING PULSE
05353 020420                    LDA 0, OMOSL
05354 061142                    DOAS 0, DIO      ; SELECT UNIT 2 REGISTER 1
05355 065142                    DOAS 1, DIO      ; OUTPUT THE TEST WORD
05356 006237                    JSR @ HZ60L      ; HOLD THE TEST WORD FOR 1/30 TH OF A SEC.
05357 006237                    JSR @ HZ60L
05360 020106                    LDA 0, MSK6
05361 107400                    AND 0, 1         ; MASK OFF THE TEST CONTROL BITS
05362 020411                    LDA 0, OMOSL
05363 061142                    DOAS 0, DIO      ; RE-SELECT UNIT 2 REGISTER 1
05364 065142                    DOAS 1, DIO      ; OUTPUT THE VALUE BITS ONLY
05365 020056                    LDA 0, P30.
05366 040164                    STA 0, TCNT1     ; SET UP A HALF SECOND LOOP COUNTER
05367 006237  STST2:            JSR @ HZ60L      ; AND HOLD THE VALUE BITS FOR A HALF SECOND
05370 014164                    DSZ TCNT1
05371 000776                    JMP STST2
05372 000744                    JMP STST0        ; WHEN DONE, GET THE NEXT TEST COMMAND

05373 140201  OMOSL:  140201
05374 140202  OM1SL:  140202

      000415                    .END PWRUP
```

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ADR1	000614	ADR3	001655	ADSR	001516	AIM	003116	ALARM	003056
ALGNO	005221	ALGN1	005266	ALGNL	000252	ALIGN	005176	ALIST	000241
ARDWP	002720	ARDWR	002721	ASBNO	002457	ASBN1	002475	ASBN2	002501
ASCO	000116	ASCBL	000224	ASCBN	002443	ASCCN	000115	ASCCR	000110
ASCDS	000111	ASCLF	002626	ASCMN	002536	ASCN	000112	ASCPS	002537
ASCPT	002755	ASCSL	000114	ASCSP	000117	ASCY	000113	AUDIO	000134
AY	001660	AZ	001661	B3.1L	000227	BA5.0	002405	BA5.1	002422
BA.2L	000225	BA.5L	000226	BCNBF	005313	BCNDY	000120	BCNDZ	000121
BCNIO	003405	BCNIN	003400	BCNSL	005142	BDDTA	005140	BECNO	005130
BECNL	000235	BECON	005105	BEGIN	001515	BIGE	003046	BIT4	000102
BIT5	000103	BIT6	000104	BIT7	000105	BN3.1	002737	BNART	002756
BNASR	002736	BNAST	002754	BNA.2	002722	BNA.5	002401	BNCTR	002533
BNDLM	002532	BNEND	002521	BNERR	002527	BNNUM	002535	BNRET	002531
BNSGN	002534	BTEST	005040	BTSTO	005046	BTST1	005076	BTST2	005056
BTST3	005100	BTSTL	000250	CENTR	005275	COMPR	001517	CONS	001757
CTRLP	003243	CTRLR	003244	DATGT	000456	DAY	000123	DEBUG	000254
DELVY	001656	DELVZ	001657	DEY	001041	DEZ	001042	DFLMB	004250
DFMBP	000171	DFMIC	000166	DFMIP	000025	DFMOC	000170	DFMOP	000167
DGENO	002261	DGEN1	002304	DGEN2	002323	DGEN3	002330	DGEN4	002170
DGEN5	002172	DGNEN	002071	DGNSL	000247	DGNST	000564	DGRST	003233
DIAG	000402	DIAGL	000253	DONE	001330	DOWN	001705	DRDIV	003354
DRSML	003246	DRST	000003	DRSTM	002712	DUD	001540	DVY	004306
DVZ	004354	ELGO	000772	ELG1	000774	ELG2	001001	ELGT	000767
ENMOD	000172	EQLC	002374	EQLCL	000231	EXPCT	003353	EXPFG	000140
EY	000153	EYL	003104	EZ	000152	EZL	003105	[illegible]	001334
FLAM1	001553	FMWDT	005330	FRFLG	000143	GNRGO	000706	GNRG1	000710
GNRGT	000675	GNRID	004242	GO	000605	GO1	000623	GRP1	001203
GRP2	001476	HESL	003107	HITAV	000136	HITFG	000137	HOURS	000125
HZ60	005143	HZ60L	000237	IMOIN	005165	IMASK	000101	IMDSL	005175
IMODO	000147	IMON	003250	INITO	000634	INOTP	000024	INT	001512
IVZ	000613	J	001513	JX	001514	KBBI	002540	KBBIL	000220
KBBLK	000175	KBB.0	002545	KBB.1	002561	KBB.2	002571	KBB.3	002573
KBB.A	002600	KBB.B	002601	KBB.C	002602	KBCI	002603	KBCI1	002622
KBCIL	000217	KBDSO	003216	KBDSV	003206	KONS	001541	LDVY	001750
LDVZ	001751	LOST	002067	MAXX	003165	MD10	001434	MD11	001455
MD12	001472	MD2	001120	MD3	001142	MD4	001171	MD5	001224

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MD6	001254	MD7	001351	MD8	001354	MD9	001414	MDIOO	003333
MDX13	001563	MFNS	003464	MFNS0	003473	MFNS1	003505	MFNS2	003525
MFNS3	003543	MFNS4	003565	MFNS5	003570	MFNSR	003575	MFOTO	003372
MFOT1	003273	MFOT2	003305	MFOT3	003314	MFOT4	003331	MFOT5	003400
MFOT6	003370	MFOT7	003276	MFOUT	003357	MINS	000126	MISFO	005155
MISFG	000141	MISFM	005150	MODIO	003410	MONTH	000122	MSBUF	000201
MSFCT	005164	MSFLB	000211	MSFMB	000200	MSFML	000236	MSK12	000107
MSK6	000106	MSK8	005141	MSLR	001316	MSLX	001265	MTEST	005000
MTSB	005022	MTSTO	005006	MTST2	005020	MTSTL	000251	NEXT	002267
NUMB	002000	NUMB3	002007	NUMB4	002031	NUMB5	002054	NWPAR	001007
NWPRL	000174	OMOSL	005373	OMISL	005374	OMODO	000150	OMOD1	000151
P100	000063	P10.	000046	P11.	000047	P12.	000050	P13.	000051
P159.	000071	P15.	000052	P177	000067	P2	000040	P200	000070
P22.	000053	P23.	000054	P24.	000055	P30.	000056	P31.	000057
P377	000072	P4	000041	P45.	000060	P5	000042	P500.	000073
P59.	000061	P6	000043	P60.	000062	P67.	000064	P7	000044
P733.	000074	P76.	000065	P99.	000066	P9.	000045	PARGO	001026
PARGT	001012	PARRT	001035	PARTM	001036	PFAIL	003172	PFALL	000400
PHI	001752	PRRST	003231	PRSML	003245	PRST	000002	PRSTM	002707
PRTBO	002642	PRTBF	002637	PRTBL	000222	PRTLL	000223	PRTLN	002641
PRTRT	002656	PWRUL	000246	PWRUP	000415	RETN1	001662	RING	003053
RNGGO	000733	RNGG1	000735	RNGGT	000732	RSTO	003236	RSTMO	002714
RTRN	001761	SAVER	003102	SBM1L	000233	SBM7L	000234	SCORE	002064
SECND	000076	SECS	000127	SEQLC	002367	SEQLL	000230	SERCH	001674
SEY	001037	SGY	001754	SHTND	000142	SKYCN	000133	SMLPL.	003463
SPDGO	000746	SPDG1	000750	SPDGT	000745	START	001044	STEP	000146
STEST	005331	STEZ	001040	STMRO	003450	STMRS	003445	STMSO	003434
STMSV	003355	STROL	003247	STRTO	001061	STRT1	001046	STRT2	001045
STSTO	005336	STST1	005352	STST2	005367	STSTL	000240	SUBM1	001755
SUBM3	002005	SUBM4	002027	SUBM5	002052	SUBM7	003000	SYSMD	000173
TACO	003344	TAC1	003345	TAC2	003346	TAC3	003347	TB10S	002430
TBHRZ	005104	TBVRT	005103	TCAR	003350	TCHGO	000673	TCHG1	000675
TCHGT	000662	TCHID	004234	TCNT	003352	TCNT1	000164	TCNT2	000165
TDDRC	002777	TDDRL	000401	TEMPO	002366	TGEL	000132	TGRNG	000130
TGSPD	000131	TIME	003103	TME	004423	TOD	002757	TODGO	000516
TODG1	000520	TODGT	000515	TODL	000216	TOF	000145	TPC	003351

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TRGEN	000144	TTCNI	002627	TTCNL	000221	TXAAL	002364	TXBBL	002365
TXTA	003576	TXTAA	004113	TXTB	003610	TXTBB	004120	TXTC	003622
TXTCC	004125	TXTD	003631	TXTDD	004145	TXTE	003643	TXTEE	004163
TXTF	003663	TXTFF	004173	TXTG	003677	TXTGG	004211	TXTH	003711
TXTHH	004221	TXTI	003725	TXTJ	003727	TXTK	003731	TXTL	003742
TXTM	003750	TXTN	003763	TXTO	003771	TXTP	004001	TXTPL	001010
TXTQ	004005	TXTQL	001011	TXTR	004010	TXTS	004014	TXTT	004017
TXTU	004022	TXTV	004065	TXTW	004070	TXTX	004075	TXTY	004103
TXTYL	002362	TXTZ	004107	TXTZL	002363	UNCLR	000077	UNPLS	000100
UPMSK	000075	UPS	003027	VESL	003106	VIDEO	000135	VY	000157
VZ	000160	WORDO	002255	WORD1	002256	WORD2	002257	WORD3	002260
X	000154	XOUT	000161	Y	000155	YB2H	005320	YB2L	005321
YBNEG	005315	YDM7	002003	YEAR	000124	YNRM	001151	YORN	002657
YORNL	000232	YOUT	000162	YP	001506	YPRNT	002332	YR	001212
YRL	001043	YRN.0	002660	YRN.1	002662	YRN.2	002674	YRN.3	002677
YRN.A	002703	YRN.B	002704	YRN.C	002705	YRN.D	002706	YS1	001504
YS2	001505	Z	000156	ZB2H	005316	ZB2L	005317	ZBNEG	005314
ZDM7	002004	ZEE	001214	ZFIL	001377	ZNRM	001233	ZOUT	000163
ZPRNT	002347	ZS1	001507	ZS2	001510	ZTOTA	001511		

APPENDIX C.--DRAGON SIMULATION GUIDANCE EQUATIONS: COMPUTER PROGRAM

CONTENTS

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This appendix shows the Johns Hopkins Applied Physics Laboratory program (fig. C-1) and its listing for the NOVA guidance equations simulation for the Dragon simulator.

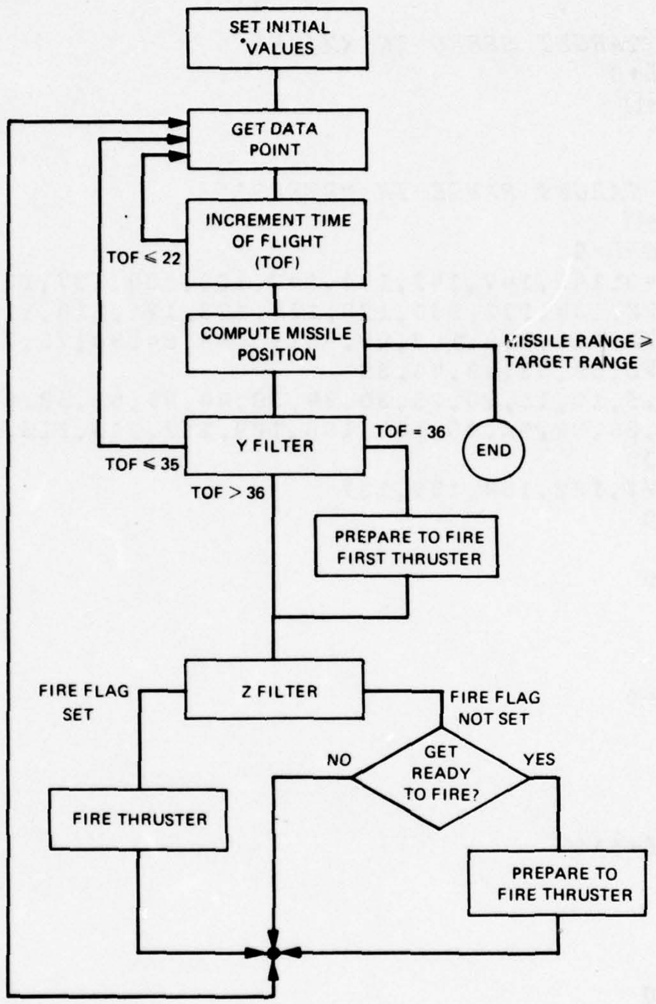

Figure C-1. Computer program for Dragon.

APPENDIX C

PROGRAM

```
 ∇SIGHT[⎕]∇
 ∇ SIGHT
 EY←0
 EZ←0
 ∇
 ∇NEW[⎕]∇
 ∇ NEW
 'READ TARGET SPEED IN KM/HR'
 STOTAL←0
 TGSPD←⎕
 EY←0
 EZ←-5
 'READ TARGET RANGE IN METERS'
 TGRNG←⎕
 YR←TGSPD×9
 DVZ←143,143,142,142,141,140,139,138,137,136
 DVZ←DVZ,134,132,130,128,126,123,121,118,115,112
 DVZ←DVZ,109,106,103,99,95,92,88,84,80,75,71,67,63
 DVZ←DVZ,58,53,48,44,39
 DVY←0,5,10,15,20,25,30,34,39,44,48,53,58,63,67,71,75,
 80,84,88,92,95,99,103,106,109,112,115,118,121,123,126,
 128,130
 DVY←DVY,132,134,136,137
 ZMAX←0
 X←0
 STEP←0
 Y←0
 Z←0
 TOF←0
 FRFLG←0
 ZS1←0
 ZS2←0
 YS1←0
 YS2←0
 ZTOTAL←115
 VY←0
 VY←0
 VZ←99
 SEY←0
 STEZ←0
START:SIGHT
 DEY←EY-SEY
 DEZ←EZ-STEZ
 SEY←EY
 STEZ←EZ
 TOF←TOF+1
 →START×⍳TOF≤22
 X←X+3
```

PROGRAM (Cont'd)

```
[40]  Y←Y+VY
[41]  Z←Z+VZ-5
[42]  ZMAX←ZMAX⌈Z
[43]  →END×⍳X>TGRNG
[44]  VZ←VZ-11
[45]  Y←Y-⌊YR×X÷TGRNG
[46]  STEP←STEP+1
[47]  Y←Y-⌊(DEY×STEP×5)÷8
[48]  YOUT←⌊Y×4÷(5×STEP)
[49]  Z←Z-⌊(DEZ×STEP×5)÷8
[50]  ZOUT←⌊Z×4÷(5×STEP)
[51]  YDF←Y-YS1
[52]  YS1←Y
[53]  YSUM←YDF+YS2
[54]  YS2←⌊YSUM×7÷8
[55]  YP←Y+2×YSUM
[56]  →START×⍳TOF≤35
[57]  SGY←1
[58]  COMPR←2294
[59]  →JUMP1×⍳YP>0
[60]  SGY←-1
[61]  YP←-YP
[62] JUMP1:PHI←⌊(YP+26)÷53
[63]  PHI←PHI⌊75
[64]  J←(⌊PHI÷2)+1
[65]  DELVZ←DVZ[J]
[66]  DELVY←-DVY[J]×SGY
[67]  PHI←PHI-20
[68]  →JUMP2×⍳PHI<0
[69]  COMPR←COMPR-(35×PHI)
[70] JUMP2:→JUMP3×⍳TOF≠36
[71]  FRFLG←1
[72]  ZS1←Z
[73]  AY←DELVY
[74]  AZ←DELVZ
[75] JUMP3:ZDF←Z-ZS1
[76]  ZS1←Z
[77]  ZSUM←ZDF+ZS2
[78]  ZS2←⌊ZSUM÷2
[79]  ZP←Z+11×ZSUM
[80]  ZTOTAL←ZTOTAL+(214-⌊ZP÷10)
[81]  →JUMP4×⍳FRFLG=0
[82]  VY←VY+AY
[83]  VZ←VZ+AZ
[84]  X,Y,Z,VY,VZ,DELVY,STOTAL,COMPR,ZMAX,YOUT,ZOUT
[85]  ZMAX←Z
[86]  FRFLG←0
[87]  →START
```

APPENDIX C

PROGRAM (Cont'd)

```
JUMP4:→START×⍳ZTOTAL<COMPR
 FRFLG←115
 STOTAL←ZTOTAL
 ZTOTAL←115
 AY←DELVY
 AZ←DELVZ
 →START
END:TGRNG,TGSPD,X,Y,Z,EY,EZ
 ∇
```

VARIABLES

Note: Time t = 1/30 s.

AY, AZ	Horizontal and vertical change in velocity when thruster is fired (millimeters/t)
DELVY, DELVZ	Horizontal and vertical change in velocity if thruster is fired at current value of angle ϕ (millimeters/t)
DVY, DVZ	Tables from which DELVY and DELVZ are taken. Values are 143 × sin ϕ and cos ϕ in 2-deg increments (millimeters/t)
DEY, DEZ	Difference between two successive values of EY and EZ (scan lines)
EY, EZ	Horizontal and vertical distance that line of sight is from center of target (scan lines)
FRFLG	Flag indicating that it is time to fire thruster
PHI	Angle measure from negative z axis indicating in which direction thruster is to be fired
SGY	Sign of angle ϕ
STEP	Number of time increments after missile exits from launch tube
TGRNG	Range to target (meters)
TGSPD	Target crossing velocity (kilometers/hour)
TOF	Time of flight, number of t intervals after trigger pull
VZ, VY	Vertical and horizontal crossing velocity of missile (millimeters/t)
X	Distance of missile from launch tube (meters)
Y, YOUT	Horizontal distance of missile from line of sight (millimeters and scan lines)
YR	Crossing velocity of target (millimeters/t)
Z, ZOUT	Vertical distance of missile from line of sight (millimeters and scan lines)

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APPENDIX D.--SYSTEM SPECIFICATION: DRAGON FLIGHT SIMULATOR

CONTENTS

TABLES

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D-1. SCOPE

This specification establishes the performance, design, development, and test requirements for the Dragon Flight Simulator (DFS).

D-2. APPLICABLE DOCUMENTS

The applicable documents will be determined later.

D-3. REQUIREMENTS

D-3.1 System Definition

D-3.1.1 General Description

The DFS shall consist of four subsystems as follows:

Dragon tracker simulator
Training/test set
Tactical target set
Training target set

a. The Dragon tracker simulator shall consist of a simulated tracker that closely resembles the tactical Dragon tracker and shall perform all the functions required for missile flight simulation and hit or miss determination when operated with targets configured with the tactical target set or the training target set. The subsystem shall provide suitable signals to an associated strap-on Multiple Integrated Laser Engagement Simulator (MILES) System laser to indicate target engagement and target kill. The subsystem shall, in addition, perform the following functions:

1. Simulate the missile flight.

2. Present an image of the missile, under control of the simulation, proceeding downrange in the sighting telescope, and present thruster firings at the correct time and roll angle.

3. Automatically range on either target set, and incorporate this range into the flight simulation to determine when a hit or a miss occurs.

4. Generate a "kill zone" of variable dimensions with reference to the upper infrared (IR) source. The placement of the kill zone with respect to the upper IR source is variable in the vertical dimension and centered on the upper IR source in the horizontal dimension.

5. Determine a hit or a miss. That is, when the simulated missile passes the target plane (as determined by the ranging function) and is contained within the kill zone envelope, the simulator scores a hit.

6. Sense the gunner's aiming motions with respect to the target, and simulate the missile flight accordingly.

7. After a hit, provide a simulated explosion centered on the missile position in the gunner's sighting telescope.

8. Provide a launch signal to the associated launch effects simulator.

9. Provide for audio and video recording of the gunner's tracking and simulated flight display.

10. Provide a realistic audible thruster sound and a hit sound.

11. Simulate distracting effects such as smoke and fog.

12. Be capable of simulating the scene and flight display seen through the night sight tracker.

b. The training/test set when connected to the Dragon tracker simulator shall perform the following functions:

1. Display video from the tracker simulator vidicon with a superimposed representation of the gunner's sighting telescope crosshairs and the kill zone.

2. Record and play back the video and audio signals from the Dragon tracker simulator.

3. Provide switching and control to allow the tracker simulator to operate on automatic ranging or a manually input range from the training/test set panel. Range, either automatic or manual, shall be displayed on the training/test set. When the simulator is in the manual range, the kill zone size shall be appropriate to the range selected.

4. At the conclusion of an engagement, provide a readout of the following: (a) range to the target at the beginning of the engagement, (b) range to the target at the end of the engagement, and (c) engagement result:

Hit (The missile passed the target plane within the kill zone.)

Miss (The missile passed the target plane outside of the kill zone.)

Short (The missile impacted with the ground; that is, it went more than 8 ft (2.4 m) below the point at which it made a transition from ballistic to guided flight, short of the target plane.)

The x and y coordinates, in meters, of the missile with respect to the kill zone center as it passes the target plane in a hit or a miss (In a short round, the range at which ground impact occurred shall be indicated.)

5. Perform the system test functions to enable the operator to determine the operability of all functions without engaging a target.

c. The tactical target set shall consist of three IR light sources and a control interface with the target MILES installation. The light sources shall be as follows:

1. One light visible 360 deg in azimuth and ±20 deg in the vertical, positioned on top of the target vehicle

2. One light visible 200 deg in azimuth and ±20 deg in the vertical, positioned in the same vertical plane normal to the target vehicle longitudinal center line as the top light and some meters (to be determined) below it on the left side of the vehicle

3. One light identical to that of item 2, but on the right side of the vehicle

The light sources shall have the option of being powered directly by the target vehicle 24-Vdc power system or by the control interface with the MILES system, in which case the lights shall be turned on at the beginning of an engagement and extinguished at the completion of the engagement.

d. The training target set shall consist of two IR light sources to be mounted on a TOW/Dragon target board and powered directly by the target vehicle 24-Vdc system. The two lights will be identical to the light described in item c.2 and mounted to the top and bottom of the target board.

D-3.1.2 <u>Mission</u>

The DFS shall be able to perform two missions: training and war games.

APPENDIX D

The DFS shall perform the training mission when configured with the Dragon tracker simulator and the training/test set interconnected and located on the training range firing line. The tracker simulator shall be attached to the launch effects simulator. The target vehicle will be any suitable vehicle such as the M151 jeep configured with a TOW/Dragon target board and the training target set. The system may be operated in either the manual or the automatic range.

When configured for war games, the Dragon tracker simulator shall operate with the launch effects simulator. The target vehicles will ordinarily be tanks or armored personnel carriers configured with the tactical target set. The system will be completely independent of fixed facilities and will be able to operate over any terrain in which the Dragon system could be employed.

D-3.1.3 Threat

The concept of threat does not apply to the DFS.

D-3.1.4 System Diagrams

System diagrams are in the User's Manual (app B of this report).

D-3.1.5 Interface Definition

The DFS shall interface with systems and devices external to itself as shown in table D-I (p. 181).

Table D-II (p. 182) defines the electrical and optical interfaces between subsystems of the DFS. There are no physical interfaces, except for electrical connections between the DFS and the training test set.

D-3.1.6 Government Furnished Property List

No Government furnished property is required.

D-3.1.7 Operational and Organizational Concept

The concepts for operation and organization will be determined later.

D-3.2 Characteristics

D-3.2.1 Performance Characteristics

The DFS shall have the following performance characteristics:

TABLE D-1. EXTERNAL INTERFACES WITH DRAGON FLIGHT SIMULATOR

External system or device	Physical interface	Electrical interface
Launch effects simulator (LES)	Dragon tracker simulator mounts to LES tube exactly as tactical Dragon tracker mates to tube.	Dragon tracker simulator provides delayed launch signal to LES; LES provides 12 Vdc at some milliamperes (to be determined) to Dragon tracker simulator.
Tactical target vehicle	Infrared (IR) light sources mount to top and both sides. Target control interface mounts adjacent to MILES control unit.	24 Vdc at 15 A is provided to target interface.
MILES target installation	-	Target control interface receives engagement in progress signals.
MILES Dragon strap-on unit	MILES mounts to Dragon tracker simulator or LES.	Dragon tracker simulator provides engagement in progress and kill signals to MILES.
Training target vehicle	-	24 Vdc at 10 A is provided to IR lights.
TOW/Dragon target board	IR light sources mount at top and bottom.	24 Vdc at 10 A is provided to IR lights.

Simulated missile flight.--The flight simulation shall employ the actual guidance equations to faithfully reproduce the flight characteristics of the Dragon missile with respect to the trajectory in response to aiming motions, velocity, thruster firings, range, and the duration of the flight.

Optical simulation.--The optical simulation of the missile and thruster firings shall be of a shape, a size, and an intensity approximating the gunner's view of a live Dragon round. The missile color shall be orange red. The thrusters shall be white and plainly visible. The visual hit indication may be a stylized representation, but must be prominent.

Aural simulation.--The aural simulation of the thruster firings and hit shall be representative of the Dragon system, shall have the appropriate duration and timing, and shall be readily heard and distinguished from one another.

TABLE D-II. SUBSYSTEM INTERFACES OF DRAGON FLIGHT SIMULATOR

From	To: Dragon tracker simulator	Training/ test set	Tactical target set	Training target set
Dragon tracker	-	Launch signal Thruster firings Hit indication Miss distance Television range Video signal Kill zone Short indication	None	None
Training/ test set	Diagnostic trigger Manual range Manual kill zone	-	None	None
Tactical target set	Infrared (IR) lights	None	-	None
Training target set	IR lights	None	None	-

<u>Automatic ranging</u>.--The automatic ranging feature shall have an accuracy of ±10 percent when used with a properly configured target.

<u>Infrared light tracking</u>.--The vidicon and logic system shall be able to maintain a 95-percent track on a moving, properly configured target under solar lighting conditions from full dark to bright day. A manual iris control may be used.

<u>Simulation of distracting effects</u>.--The system shall be able to simulate distracting effects such as smoke and fog.

<u>Simulation of missile flight</u>.--The system shall be able to simulate the scene and missile flight display seen through the night sight tracker.

D-3.2.2 Physical Characteristics

The weight limitations for the elements of the DFS are as follows:

Dragon tracker simulator: 15 lb (6.8 kg) for tracker and 25 lb (11.3 kg) for spare round containing power supply and other electronics

Training/test set: 100 lb (44.8 kg)

Tactical target set: 40 lb (17.92 kg)

Training target set: 20 lb (8.9 kg)

The elements of the DFS shall conform to the following dimensional criteria:

Dragon tracker simulator.--The Dragon tracker simulator shall be contained within the approximate envelope of the Dragon tracker. Minor deviations from the Dragon tracker envelope are permitted for ease of packaging and maintenance, but dimensional integrity of the points of gunner interface--that is, eyepiece, left hand grip, and trigger assembly--shall be maintained.

Training/test set.--The training/test set shall be of a size and a shape to be easily handled by two men.

Tactical target set.--The tactical target set shall be sized to present minimum changes to the target vehicle profile and clearances while having the required angular visibility.

Training target set.--The training target set shall be sized to obscure no more of the TOW/Dragon target board than necessary. Rotation of the target board when mounted in an M151 jeep shall be possible without interference.

The DFS shall be transportable as follows:

Dragon tracker simulator: in the tactical Dragon tracker carrying case or attached to a launch tube or launch effects simulator

Training/test set: in an integral case

Tactical target set: in a carrying case or mounted on the target vehicle

Training target set: in a carrying case or mounted on the TOW/Dragon target board

Storage shall be as configured for transport or use.

The elements of the DFS shall be of a durability suitable for the intended use.

D-3.2.3 Reliability

Reliability of the DFS will be determined later.

D-3.2.4 Maintainability

Maintainability of the DFS will be determined later.

D-3.2.5 Availability

Availability of the DFS will be determined later.

D-3.2.6 System Effectiveness Models

No system effectiveness models are applicable.

D-3.2.7 Environmental Conditions

The environmental conditions for optimum performance of the DFS will be determined later.

D-3.2.8 Nuclear Control Requirements

No nuclear control requirements are applicable.

D-3.3 Design and Construction

The design and construction of the DFS shall conform to the required specifications.

D-3.4 Documentation

Documentation will be determined later.

D-3.5 Logistics

Logistics will be determined later.

D-3.6 Personnel and Training

Needs for personnel and their training will be determined later.

D-3.7 Functional Area Characteristics

Functional area characteristics are not applicable.

D-3.8 Precedence

Precedence will be determined later.

D-4. QUALITY ASSURANCE PROVISIONS

Provisions for quality assurance will be determined later.

D-5. PREPARATION FOR DELIVERY

Preparation for delivery will be determined later.

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